
TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
NOTICE	ii
FOREWORD	iii
ABSTRACT	iv
ACKNOWLEDGEMENTS	x
 SITE PROGRAM DESCRIPTION	 1
SITE PROGRAM CONTACTS	6
 DEMONSTRATION PROGRAM	 7
 <u>Completed Demonstration Program Projects</u>	
 Active Environmental, Inc.	
(TECHXTRACT® Process)	20
American Combustion, Inc. (PYRETRON® Thermal Destruction)	22
ARS Technologies, Inc. (Pneumatic Fracturing Extraction SM and Catalytic Oxidation)	24
Bergmann, A Division of Linatex, Inc. (Soil and Sediment Washing)	26
Berkeley Environmental Restoration Center	
(In Situ Steam Enhanced Extraction Process)	28
Billings and Associates, Inc.	
(Subsurface Volatilization and Ventilation System [SVVS®])	30
BioGenesisSM Enterprises, Inc.	
(BioGenesis SM Soil and Sediment Washing Process)	32
Bio-Rem, Inc. (Augmented In Situ Subsurface Bioremediation Process)	34
Biotherm, LCC (Biotherm Process TM)	36
BioTrol® (Biological Aqueous Treatment System)	38
BioTrol® (Soil Washing System)	40
Brice Environmental Services Corporation (Soil Washing Process)	42
BWX Technologies, Inc. (affiliated with Babcock & Wilcox Co.)	
(Cyclone Furnace)	44
Calgon Carbon Advanced Oxidation Technologies	
(perox-pure TM Chemical Oxidation Technology)	46
CF Systems Corporation	
(Liquified Gas Solvent Extraction [LG-SX] Technology)	48
Chemfix Technologies, Inc. (Solidification and Stabilization)	50
COGNIS, Inc. (TERRAMET® Soil Remediation System)	52
Colorado Department of Public Health and Environment	
(Constructed Wetlands-Based Treatment)	54
Commodore Applied Technologies, Inc.	
(Solvated Electron Technology, SET TM Remediation System)	56
Cure International, Inc. (CURE®-Electrocoagulation Wastewater Treatment System)	58

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
<u>Completed Demonstration Program Projects (continued)</u>	
E.I. DuPont de Nemours and Company, and	
Oberlin Filter Company (Membrane Microfiltration)	60
Dynaphore, Inc. (FORAGER® Sponge)	62
ECOVA Corporation (Bioslurry Reactor)	64
Electrokinetics, Inc. (Electrokinetic Soil Processing)	66
ELI Eco Logic Inc. (Gas-Phase Chemical Reduction Process)	68
ELI Eco Logic International Inc. (Thermal Desorption Unit)	70
EnviroMetal Technologies Inc. (In Situ and Ex Situ Metal-Enhanced Abiotic Degradation of Dissolved Halogenated Organic Compounds in Groundwater)	72
EPOC Water, Inc. (Precipitation, Microfiltration, and Sludge Dewatering)	74
Filter Flow Technology, Inc. (Colloid Polishing Filter Method®)	76
Funderburk & Associates (Dechlorination and Immobilization)	78
General Atomics (Circulating Bed Combustor)	80
Geo-Con, Inc. (In Situ Solidification and Stabilization Process)	82
Geosafe Corporation (GeoMelt Vittrification)	84
Geotech Development Corporation (Cold Top Ex-Situ Vittrification of Chromium-Contaminated Soils)	86
GIS\Solutions, Inc. (GIS\Key™ Environmental Data Management System)	88
GRACE Bioremediation Technologies (DARAMEND™ Bioremediation Technology)	90
Gruppo Italimprese (Infrared Thermal Destruction)	92
High Voltage Environmental Applications, Inc. (High-Energy Electron Irradiation)	94
Horsehead Resource Development Co., Inc. (Flame Reactor)	96
Hrubetz Environmental Services, Inc. (HRUBOUT® Process)	98
Hughes Environmental Systems, Inc. (Steam Enhanced Recovery Process)	100
IIT Research Institute/Brown and Root Environmental (Radio Frequency Heating)	102
Ionics RCC (B.E.S.T. Solvent Extraction Technology)	104
KAI Technologies, Inc./Brown and Root Environmental (Radio Frequency Heating)	106
Magnum Water Technology (CAV-OX® Process)	108
Matrix Photocatalytic Inc. (Photocatalytic Water Treatment)	110
Maxymillian Technologies, Inc. (Thermal Desorption System)	112
Morrison Knudsen Corporation/Spetstamponazhgeologia Enterprises (Clay-Base Grouting Technology)	114
National Risk Management Research Laboratory (Base-Catalyzed Decomposition Process)	116
National Risk Management Research Laboratory (Volume Reduction Unit)	118
National Risk Management Research Laboratory and INTECH 180 Corporation (Fungal Treatment Technology)	120
National Risk Management Research Laboratory and IT Corporation (Debris Washing System)	122

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
<u>Completed Demonstration Program Projects (continued)</u>	
National Risk Management Research Laboratory, University of Cincinnati, and FRX, Inc. (Hydraulic Fracturing)	124
New York State Department of Environmental Conservation/ ENSR Consulting and Engineering and Larsen Engineers (Ex Situ Biovault)	126
New York State Department of Environmental Conservation/ SBP Technologies, Inc. (Vacuum-Vaporized Well System)	128
New York State Department of Environmental Conservation/ R.E. Wright Environmental, Inc. (In Situ Bioventing Treatment System)	130
North American Technologies Group, Inc. (Oleophilic Amine-Coated Ceramic Chip)	132
NOVATERRA Associates (In Situ Soil Treatment [Steam and Air Stripping])	134
OHM Remediation Services Corp. (X*TRAX™ Thermal Desorption)	136
Radian International LCC (Integrated AquaDetox Steam Vacuum Stripping and Soil Vapor Extraction/Reinjection)	138
Remediation Technologies, Inc. (Liquid and Solids Biological Treatment)	140
Rochem Separation Systems, Inc. (Rochem Disc Tube™ Module System)	142
SBP Technologies, Inc. (Membrane Filtration and Bioremediation)	144
J.R. Simplot Company (The SABRE™ Process)	146
Smith Environmental Technologies Corporation (Low Temperature Thermal Aeration [LTTA®])	148
SoilTech ATP Systems, Inc. (Anaerobic Thermal Processor)	150
Soliditech, Inc. (Solidification and Stabilization)	152
Sonotech, Inc. (Frequency-Tunable Pulse Combustion System)	154
STC Remediation, A Division of Omega Environmental, Inc. (Organic Stabilization and Chemical Fixation/Solidification)	156
Terra-Kleen Response Group, Inc. (Solvent Extraction Treatment System)	158
Terra Vac (In Situ and Ex Situ Vacuum Extraction)	160
Texaco Inc. (Texaco Gasification Process)	162
Toronto Harbour Commission (Soil Recycling)	164
U.S. Filter/WTS Ultrox (Ultraviolet Radiation and Oxidation)	166
United States Environmental Protection Agency (Excavation Techniques and Foam Suppression Methods)	168
University of Nebraska - Lincoln (Center Pivot Spray Irrigation System)	170
WASTECH, Inc. (Solidification and Stabilization)	172
Roy F. Weston, Inc. (Low Temperature Thermal Treatment System)	174
Roy F. Weston, Inc./IEG Technologies (UVB - Vacuum Vaporizing Well)	176
Wheelabrator Clean Air Systems, Inc. (PO*WW*ER™ Technology)	178
Xerox Corporation (2-PHASE™ EXTRACTION Process)	180

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
<u>Completed Demonstration Program Projects (continued)</u>	
ZENON Environmental Inc. (Cross-Flow Pervaporation System)	182
ZENON Environmental Inc. (ZenoGem™ Process)	184
<u>Ongoing Demonstration Program Projects</u>	
Arctic Foundations Inc. (Cryogenic Barrier)	190
Duke Engineering (Surfactant Enhanced Aquifer Remediation of Nonaqueous Phase Liquids)	192
Envirometal Technologies, Inc. (Reactive Barrier)	194
Geokinetics International, Inc. (Electroheat-Enhanced Nonaqueous-Phase Liquids Removal)	196
ITT Night Vision (In situ Enhanced Bioremediation of Groundwater)	198
KSE, Inc. (Adsorption-Integrated-Reaction Process)	200
Lasagna Public-Private Partnership (Lasagna In Situ Soil Remediation)	202
Matrix Photocatalytic Inc. (Photocatalytic Air Treatment)	206
National Risk Management Research Laboratory (Bioventing)	208
Phytokinetics, Inc. (Phytoremediation Process)	210
Phytotech (Phytoremediation Technology)	212
Pintail Systems Incorporated (Spent Ore Bioremediation Process)	214
Praxis Environmental Technologies, Inc. (In Situ Thermal Extraction Process)	216
Process Technologies, Inc. (Photolytic Destruction of Vapor-Phase Halogens)	218
Recycling Sciences International, Inc. (Desorption and Vapor Extraction System)	220
Rocky Mountain Remediation Services, L.L.C. (Envirobond™ Solutions)	222
Sandia National Laboratories (In Situ Electrokinetic Extraction System)	224
Selentec Environmental Technologies, Inc. (Selentec MAG*SEP SM Technology)	226
Sevenson Environmental Services, Inc. (MAECTITE® Chemical Treatment Process) ...	228
SIVE Services (Steam Injection and Vacuum Extraction)	230
Star Organics, L.L.C. (Soil Rescue Remediation Fluid)	232
U.S. Air Force (Phytoremediation of TCE-Contaminated Shallow Groundwater)	234
Vortec Corporation (Oxidation and Vitrification Process)	236
 DOCUMENTS AVAILABLE FROM THE U.S. EPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY, SUPERFUND TECHNOLOGY DEMONSTRATION DIVISION	
VIDEO REQUEST FORM	239
TRADE NAME INDEX	251
APPLICABILITY INDEX	255
	265

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	DEVELOPMENT OF INNOVATIVE TECHNOLOGIES	2
2	INNOVATIVE TECHNOLOGIES IN THE DEMONSTRATION PROGRAM	3
3	INNOVATIVE TECHNOLOGIES IN THE EMERGING TECHNOLOGY PROGRAM	4

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	COMPLETED SITE DEMONSTRATION PROGRAM PROJECTS AS OF OCTOBER 1998	8
2	ONGOING SITE DEMONSTRATION PROGRAM PROJECTS AS OF OCTOBER 1998	186

ACTIVE ENVIRONMENTAL, INC. (formerly EET, Inc. TECHXTRACT® Process)

TECHNOLOGY DESCRIPTION:

The TECHXTRACT® process employs patented chemical formulations in successive steps to remove polychlorinated biphenyls (PCB), toxic hydrocarbons, heavy metals, and radionuclides from the subsurface of porous materials such as concrete, brick, steel, and asphalt (see figure below). Each formulation consists of chemicals from up to 14 separate chemical groups, and each formulation can be specifically tailored to each contaminated site.

The process is performed in multiple cycles. Each cycle consists of three stages: surface preparation, extraction, and rinsing. Each stage employs a specific chemical mix.

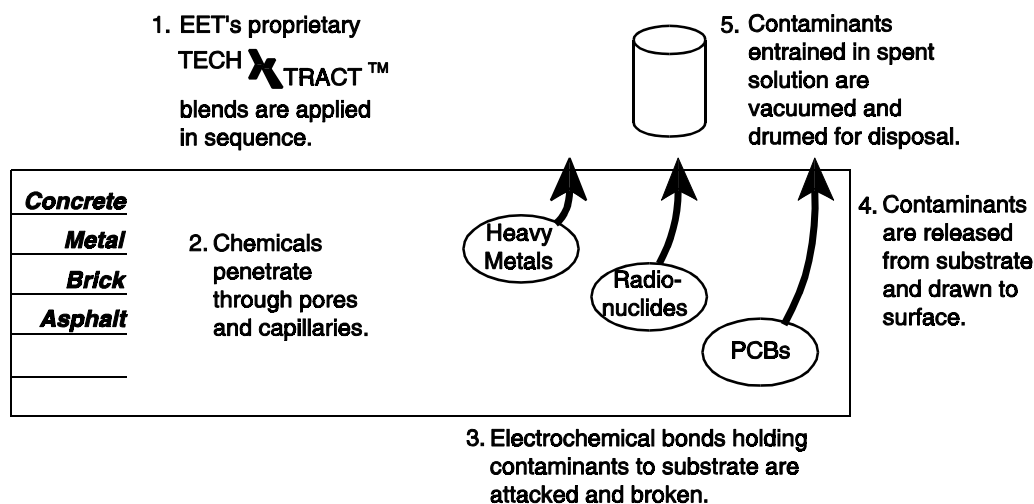
The surface preparation step uses a solution that contains buffered organic and inorganic acids, sequestering agents, wetting agents, and special hydrotrope chemicals. The extraction formula includes macro- and microemulsifiers in addition to electrolyte, flotation, wetting, and sequestering agents. The rinsing formula is pH-balanced and contains wetting and complexing

agents. Emulsifiers in all the formulations help eliminate fugitive releases of volatile organic compounds or other vapors. The chemical formulation in each stage is sprayed on the contaminated surface as a fine mist and worked into the surface with a stiff bristle brush or floor scrubber. The chemicals are allowed to penetrate into the subsurface and are then rinsed and vacuumed from the surface with a high-efficiency, particulate air-filtered, barrel-vacuum. No major capital equipment is required.

Contaminant levels can be reduced from 60 to 90 percent per cycle. One cycle can take up to 24 hours. The total number of cycles is determined from initial contaminant concentrations and final concentration target levels.

WASTE APPLICABILITY:

The TECHXTRACT® process is designed to treat porous solid materials contaminated with PCBs; toxic hydrocarbons such as pesticides; heavy metals, including lead and arsenic; and radionuclides. Because the contaminants are extracted from the surface, the materials can be



Process Flow Diagram of the TECHXTRACT® Process

left in place, reused, or recycled. After treatment, the contaminants are concentrated in a small volume of liquid waste.

In commercial applications, the process has reduced PCB concentrations from 1,000,000 micrograms per 100 square centimeters ($\mu\text{g}/100\text{ cm}^2$) to concentrations less than $0.2\text{ }\mu\text{g}/100\text{ cm}^2$. Core samples have shown removals from up to 4 inches deep in concrete. The TECHXTRACT® process has been used on concrete floors, walls and ceilings, tools and machine parts, internal piping, valves, and lead shielding. The TECHXTRACT® process has removed lead, arsenic, technetium, uranium, cesium, tritium, and thorium.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1994. The demonstration was successfully completed at the Pearl Harbor Naval Complex in April 1997. A video tape of that demonstration is available from the Technology Developer.

The technology has been used in over 400 successful decontamination projects for the U.S. Department of Energy; U.S. Department of Defense; the electric, heavy manufacturing, steel, and aluminum industries; and other applications. Active Environmental, Inc. has developed methods for removing or concentrating metals, particularly radionuclides, in the extracted liquids.

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AMERICAN COMBUSTION, INC.
(PYRETRON® Thermal Destruction)

TECHNOLOGY DESCRIPTION:

The PYRETRON® thermal destruction technology controls the heat input during incineration by controlling excess oxygen available to oxidize hazardous waste (see figure below). The PYRETRON® combustor relies on a new technique for mixing auxiliary oxygen, air, and fuel to (1) provide the flame envelope with enhanced stability, luminosity, and flame core temperature, and (2) increase the rate of heat released.

The technology is computer-controlled to automatically adjust the temperatures of the primary and secondary combustion chambers and the amount of excess oxygen. The system adjusts the amount of excess oxygen in response to sudden changes in contaminant volatilization rates in the waste.

The technology fits any conventional incineration unit and can burn liquids, solids, and sludges.

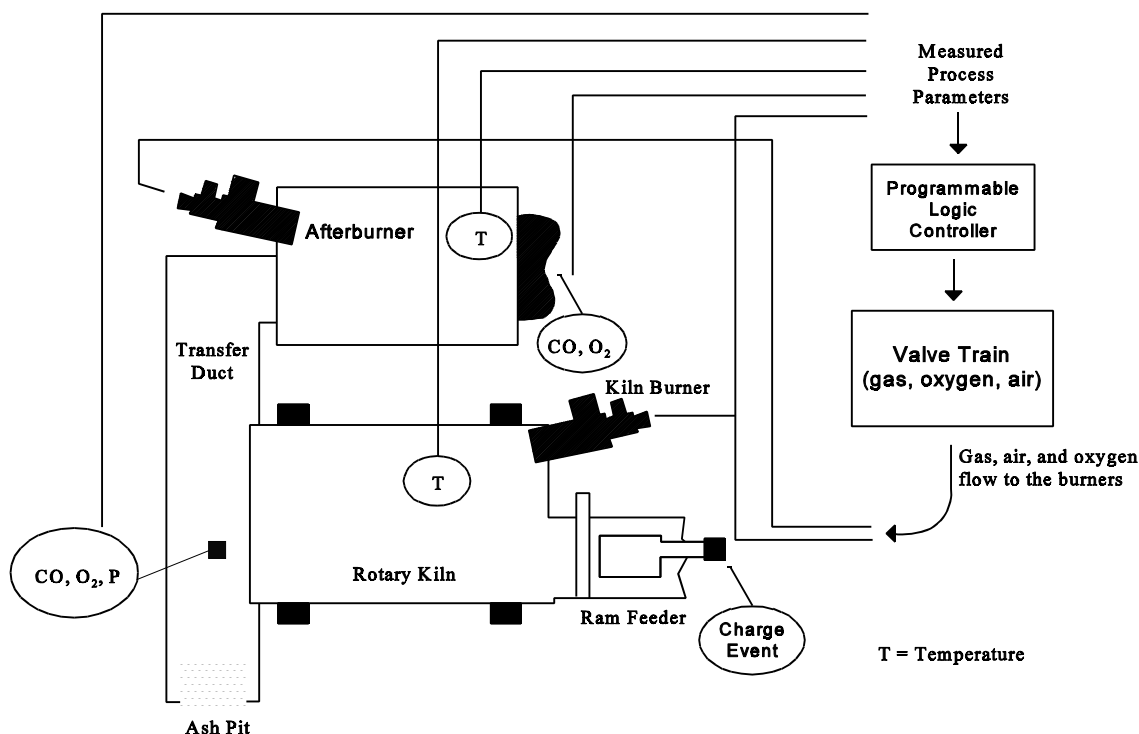
Solids and sludges can also be coincinerated when the burner is used with a rotary kiln or similar equipment.

WASTE APPLICABILITY:

The PYRETRON® technology treats high- and low-British thermal unit solid wastes contaminated with rapidly volatilized hazardous organics. In general, the technology treats any waste that can be incinerated. It is not suitable for processing Resource Conservation and Recovery Act heavy metal wastes or inorganic wastes.

STATUS:

The PYRETRON® technology was demonstrated at EPA's Incineration Research Facility in Jefferson, Arkansas, using a mixture of 40 percent contaminated soil from the Stringfellow Acid Pit Superfund site in Glen Avon, California and 60 percent decanter tank tar sludge (K087)



PYRETRON® Thermal Destruction System

from coking operations. The demonstration began in November 1987 and was completed at the end of January 1988.

Both the Innovative Technology Evaluation Report (EPA/540/5-89/008) and Applications Analysis Report (EPA/540/A5-89/008) are available from EPA.

DEMONSTRATION RESULTS:

The polynuclear aromatic hydrocarbons naphthalene, acenaphthylene, fluorene, phenanthrene, anthracene, and fluoranthene were selected as the principal organic hazardous constituents (POHC) for the demonstration. The PYRETRON® technology achieved greater than 99.99 percent destruction and removal efficiencies for all six POHCs in all test runs. Other results are listed below:

- The PYRETRON® technology with oxygen enhancement doubled the waste throughput possible with conventional incineration.
- All particulate emission levels from the scrubber system discharge were significantly below the hazardous waste incinerator performance standard of 180 milligrams per dry standard cubic meter at 7 percent oxygen. This standard was in place until May 1993.
- Solid residues were contaminant-free.

- There were no significant differences in transient emissions of carbon monoxide between air-only incineration and PYRETRON® oxygen-enhanced operation with doubled throughput rate.
- Cost savings increase when operating and fuel costs are high and oxygen costs are relatively low.
- The system can double the capacity of a conventional rotary kiln incinerator. This increase is more significant for wastes with low heating values.

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ARS Technologies, Inc.
(formerly Accutech Remedial Systems, Inc.)
(Pneumatic Fracturing ExtractionSM and Catalytic Oxidation)

TECHNOLOGY DESCRIPTION:

Accutech Remedial Systems, Inc. (Accutech), and the Hazardous Substance Management Research Center at the New Jersey Institute of Technology in Newark, New Jersey have jointly developed an integrated treatment system that combines Pneumatic Fracturing ExtractionSM (PFESM) with catalytic oxidation. According to Accutech, the system provides a cost-effective, accelerated approach for remediating less permeable formations contaminated with halogenated and nonhalogenated volatile organic compounds (VOC) and semivolatile organic compounds (SVOC).

The Accutech system forces compressed gas into a geologic formation at pressures that exceed the

natural in situ stresses, creating a fracture network. These fractures allow subsurface air to circulate faster and more efficiently throughout the formation, which can greatly improve contaminant mass removal rates. PFESM also increases the effective area that can be influenced by each extraction well, while intersecting new pockets of contamination that were previously trapped in the formation. Thus, VOCs and SVOCs can be removed faster and from a larger section of the formation.

PFESM can be combined with a catalytic oxidation unit equipped with special catalysts to destroy halogenated organics (see photograph below). The heat from the catalytic oxidation unit can be recycled to the formation, significantly raising the vapor pressure of the



contaminants. Thus, VOCs and SVOCs volatilize faster, making cleanup more efficient. PFESM can also be combined with hot gas injection (HGI), an in situ thermal process, to further enhance VOC and SVOC removal rates. HGI returns to the ground the energy generated during catalytic oxidation of the VOCs.

WASTE APPLICABILITY:

The Accutech system can remove halogenated and nonhalogenated VOCs and SVOCs from both the vadose and saturated zones. The integrated treatment system is cost-effective for treating soil and rock when less permeable geologic formations limit the effectiveness of conventional in situ technologies.

According to Accutech, the PFESM-HGI integrated treatment system is cost-effective for treating less permeable soil and rock formations where conventional in situ technologies have limited effectiveness. Activated carbon is used when contaminant concentrations decrease to levels where catalytic oxidation is no longer cost-effective.

STATUS:

The Accutech technology was accepted into the SITE Demonstration Program in December 1990. The demonstration was conducted in summer 1992 at a New Jersey Department of Environmental Protection and Energy Environmental Cleanup Responsibility Act site in

Hillsborough, New Jersey. During the demonstration, trichloroethene and other VOCs were removed from a siltstone formation. Results of this demonstration were published in the following documents available from EPA:

- Technology Evaluation Report (EPA/540/R-93/509)
- Technology Demonstration Summary (EPA/540/SR-93/509)
- Demonstration Bulletin (EPA/540/MR-93/509)
- Applications Analysis Report (EPA/540/AR-93/509)

DEMONSTRATION RESULTS:

The demonstration results indicate that PFESM increased the effective vacuum radius of influence nearly threefold. PFESM also increased the rate of mass removal up to 25 times over the rates measured using conventional extraction technology.

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BERGMANN, A DIVISION OF LINATEX, INC. (Soil and Sediment Washing)

TECHNOLOGY DESCRIPTION:

The soil and sediment washing technology developed by Bergmann, A Division of Linatex, Inc.'s, (Bergman), separates contaminated particles by density and grain size (see photograph below). The technology operates on the hypothesis that most contamination is concentrated in the fine particle fraction (less than 45 microns [μm]) and that contamination of larger particles is generally not extensive.

After contaminated soil is screened to remove coarse rock and debris, water and chemical additives such as surfactants, acids, bases, and chelators are added to the medium to produce a slurry feed. The slurry feed flows to an attrition scrubbing machine. A rotary trommel screen, dense media separators, cyclone separators, and

other equipment create mechanical and fluid shear stress, removing contaminated silts and clays from granular soil particles.

Different separation processes create the following four output streams: (1) coarse clean fraction; (2) enriched fine fraction; (3) separated contaminated humic materials; and (4) process wash water. The coarse clean fraction particles, which measure greater than 45 μm (greater than 325 mesh) each, can be used as backfill or recycled for concrete, masonry, or asphalt sand application. The enriched fine fraction particles, measuring less than 45 μm each are prepared for subsequent treatment, immobilization, destruction, or regulated disposal. Separated contaminated humic materials (leaves, twigs, roots, grasses, wood chips) are dewatered and require subsequent treatment or disposal. Upflow classification and



Bergmann Soil and Sediment Washing

separation, also known as elutriation, separates light contaminated materials such as leaves, twigs, roots, or wood chips. The process wash water is treated by flocculation and sedimentation, oil-water separation, or dissolved air flotation to remove solubilized heavy metal and emulsified organic fractions. The treated process wash water is then returned to the plant for reuse.

WASTE APPLICABILITY:

This technology is suitable for treating soils and sediment contaminated with organics, including polychlorinated biphenyls (PCB), creosote, fuel residues, and heavy petroleum; and heavy metals, including cadmium, chromium, lead, arsenic, copper, cyanides, mercury, nickel, radionuclides, and zinc.

STATUS:

This technology was accepted into the SITE Demonstration Program in Winter 1991. It was demonstrated in Toronto, Ontario, Canada in April 1992 as part of the Toronto Harbour Commission (THC) soil recycling process. For further information on the THC process, including demonstration results, refer to the THC profile in the Demonstration Program section (completed projects). The technology was also demonstrated in May 1992 at the Saginaw Bay Confined Disposal Facility in Saginaw, Michigan. The Applications Analysis Report (EPA/540/AR-92/075) and the Demonstration Bulletin (EPA/540/MR-92/075) are available from EPA. Since 1981, Bergmann has provided 31 commercial systems, treating up to 350 tons per hour, at contaminated waste sites.

DEMONSTRATION RESULTS:

Demonstration results indicate that the soil and sediment washing system can effectively isolate and concentrate PCB contamination into the organic fractions and the fines. Levels of metals contamination were also beneficially altered from the feed stream to the output streams. The effectiveness of the soil and sediment washing system on the inorganic compounds met or

exceeded its performance for PCB contamination. During a 5-day test in May 1992, the Bergmann soil and sediment washing system experienced no downtime as it operated for 8 hours per day to treat dredged sediments from the Saginaw River.

The demonstration provided the following results:

- Approximately 71 percent of the particles smaller than 45- μ m in the input sediment was apportioned to the enriched fine stream.
- Less than 20 percent of the particles smaller than 45- μ m in the input sediment was apportioned to the coarse clean fraction.
- The distribution of the concentrations of PCBs in the input and output streams were as follows:
 - Input sediment = 1.6 milligrams per kilogram (mg/kg)
 - Output coarse clean fraction = 0.20 mg/kg
 - Output humic materials = 11 mg/kg
 - Output enriched fines = 4.4 mg/kg
- The heavy metals were concentrated in the same manner as the PCBs.
- The coarse clean sand consisted of approximately 82 percent of the input sediment.

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BERKELEY ENVIRONMENTAL RESTORATION CENTER (In Situ Steam Enhanced Extraction Process)

TECHNOLOGY DESCRIPTION:

The in situ steam enhanced extraction (ISEE) process removes volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated water and soils above and below the water table (see figure below). Pressurized steam is introduced through injection wells to force steam through the soil to thermally enhance the vapor and liquid extraction processes.

The extraction wells have two purposes: (1) to pump groundwater for ex situ treatment; and (2) to transport steam and vaporized contaminants under vacuum to the surface. Recovered contaminants are condensed and recycled, processed with the contaminated groundwater, or treated in the gas phase. The ISEE process uses readily available components such as injection, extraction, and monitoring wells; manifold piping; vapor and liquid separators; vacuum pumps; and gas emission control equipment.

WASTE APPLICABILITY:

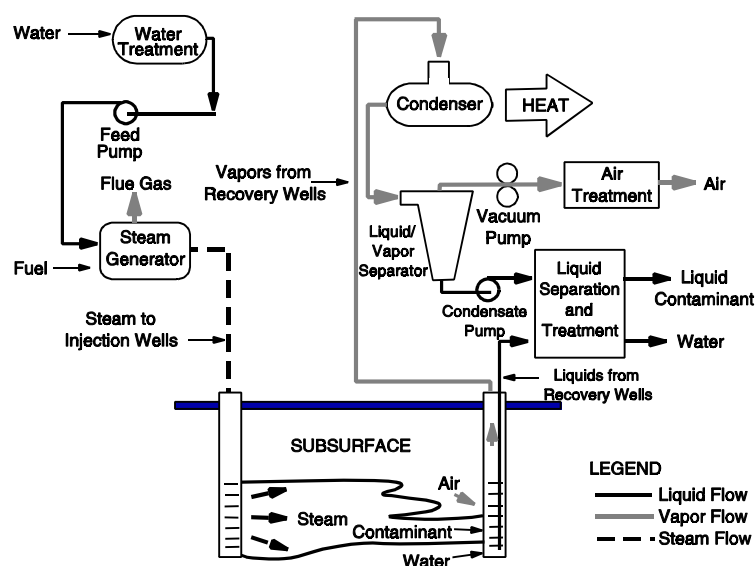
The ISEE process extracts VOCs and SVOCs from contaminated soils and groundwater. The primary compounds suitable for treatment include

hydrocarbons such as gasoline, diesel, and jet fuel; solvents such as trichloroethene, 1,1,1-trichloroethane, and dichlorobenzene; or a mixture of these compounds. The process may be applied to contaminants above or below the water table. After treatment is complete, subsurface conditions are amenable to biodegradation of residual contaminants, if necessary. The process can be applied to contaminated soil very near the surface with a cap. Compounds denser than water may be treated only in low concentrations, unless a barrier exists or can be created to prevent downward percolation of a separate phase.

STATUS:

In August 1988, a successful pilot-scale demonstration of the ISEE process was completed at a site contaminated with a mixture of solvents. Contaminants amounting to 764 pounds were removed from the 10-foot-diameter, 12-foot-deep test region. After 5 days of steam injection, soil contaminant concentrations dropped by a factor of 10.

In December 1993, a full-scale demonstration was completed at a gasoline spill site at Lawrence Livermore National Laboratory (LLNL) in



In Situ Steam Enhanced Extraction Process

Altamont Hills, California. Gasoline was dispersed both above and below the water table due to a 25-foot rise in the water table since the spill occurred. The lateral distribution of liquid-phase gasoline was within a region 150 feet in diameter and up to 125 feet deep. Appendix A of the Hughes Environmental Systems Innovative Technology Evaluation Report (EPA/540/R-94/510) contains detailed results from the LLNL SITE demonstration. This report is available from EPA.

A pilot-scale test of the ISEE process was conducted in 1994 at Naval Air Station (NAS) Lemoore in California. During 3 months of operation, over 98,000 gallons of JP-5 jet fuel was recovered from medium permeability, partially saturated sand to a depth of 20 feet. Preliminary soil sampling showed reductions of JP-5 jet fuel concentrations from several thousand parts per million (ppm) above the water table to values less than 25 ppm.

During Fall 1998, Berkeley is scheduled to use the ISEE process to remediate a groundwater contaminant plume at Alameda Naval Air Station in California. The contaminant plume contains halogenated organic compounds, including trichloroethene, 1,1,1-trichloroethane, and perchloroethylene.

For more information about similar technologies, see the following profiles in the Demonstration Program section: Hughes Environmental Systems, Inc., (completed projects) and Praxis Environmental Technologies, Inc. (ongoing projects).

DEMONSTRATION RESULTS:

During the SITE demonstration at LLNL, over 7,600 gallons of gasoline were recovered from above and below the water table in 26 weeks of operation. Recovery rates were about 50 times greater than those achieved by vacuum extraction and groundwater pumping alone. The rates were

highest during cyclic steam injection, after subsurface soils reached steam temperatures. The majority of the recovered gasoline came from the condenser as a separate phase liquid or in the effluent air stream.

Without further pumping, 1,2-dichloroethene, benzene, ethylbenzene, toluene, and xylene concentrations in sampled groundwater were decreased to below maximum contaminant levels after 6 months. Post-process soil sampling indicated that a thriving hydrocarbon-degrading microbial population existed in soils experiencing prolonged steam contact.

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BILLINGS AND ASSOCIATES, INC.

(Subsurface Volatilization and Ventilation System [SVVS®])

TECHNOLOGY DESCRIPTION:

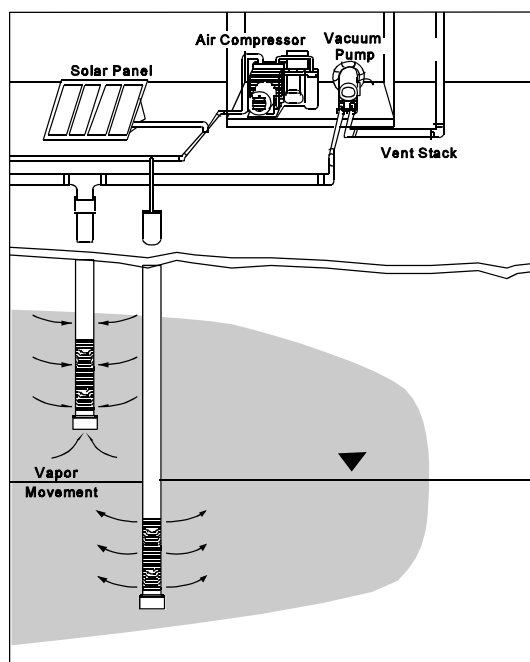
The Subsurface Volatilization and Ventilation System (SVVS®), developed by Billings and Associates, Inc. (BAI), and operated by several other firms under a licensing agreement, uses a network of injection and extraction wells (collectively called a reactor nest) to treat subsurface organic contamination through soil vacuum extraction combined with in situ biodegradation. Each system is designed to meet site-specific conditions. The SVVS® technology has three U.S. patents.

The SVVS® is shown in the figure below. A series of injection and extraction wells is installed at a site. One or more vacuum pumps create negative pressure to extract contaminant vapors, while an air compressor simultaneously creates positive pressure, sparging the subsurface treatment area. Control is maintained at a vapor control unit that houses pumps, control valves, gauges, and other process control hardware.

At most sites with subsurface organic contamination, extraction wells are placed above the water table and injection wells are placed below the groundwater. This placement allows the groundwater to be used as a diffusion device.

The number and spacing of the wells depends on the modeling results of a design parameter matrix, as well as the physical, chemical, and biological characteristics of the site. The exact depth of the injection wells and screened intervals are additional design considerations.

To enhance vaporization, solar panels are occasionally used to heat the injected air. Additional valves for limiting or increasing air flow and pressure are placed on individual reactor nest lines (radials) or, at some sites, on individual well points. Depending on groundwater depths and fluctuations, horizontal vacuum screens, "stubbed" screens, or multiple-depth completions can be applied. Positive and negative air flow can be shifted to different locations at the site to



Subsurface Volatilization and Ventilation System (SVVS®)

emphasize remediation on the most contaminated areas. Negative pressure is maintained at a suitable level to prevent escape of vapors.

Because it provides oxygen to the subsurface, the SVVS® can enhance in situ bioremediation at a site, thereby decreasing remediation time. These processes are normally monitored by measuring dissolved oxygen levels in the aquifer, recording carbon dioxide levels in transmission lines and at the emission point, and periodically sampling microbial populations. When required by air quality permits, volatile organic compound emissions can be treated by a patent-pending biological filter that uses indigenous microbes from the site.

WASTE APPLICABILITY:

The SVVS® is applicable to soils, sludges, and groundwater contaminated with gasoline, diesel fuels, and other hydrocarbons, including halogenated compounds. The technology is effective on benzene, toluene, ethylbenzene, and xylene contamination. It can also contain contaminant plumes through its unique vacuum and air injection techniques.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1991. A site in Buchanan, Michigan was selected for the demonstration, and initial drilling and construction began in July 1992. The demonstration began in March 1993 and was completed in May 1994. The Demonstration Bulletin (EPA/540/MR-94/529), Technology Capsule (EPA/540/R-94/529a), and Innovative Technology Evaluation Report (EPA/540/R-94/529) are available from EPA. The SVVS® has also been implemented at 95 underground storage tank sites in New Mexico, North Carolina, South Carolina, Florida, and Oklahoma.

BAI is researching ways to increase the microbiological effectiveness of the technology and is testing a mobile unit. The mobile unit will allow rapid field pilot tests to support the design process. This unit will also permit actual

remediation of small sites and of small, recalcitrant areas on large sites.

DEMONSTRATION RESULTS:

Results from the SVVS® demonstration are as follows:

- Data indicated that the overall reductions for several target analytes, as determined from individual boreholes, ranged from 71 percent to over 99 percent, over a 1-year period.
- The early phase of the remediation was characterized by higher concentrations of volatile organics in the extracted vapor stream.
- The shutdown tests indicate that the technology stimulated biodegradative processes at the site.

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BIOGENESIS ENTERPRISES, INC. (BioGenesisSM Soil and Sediment Washing Process)

TECHNOLOGY DESCRIPTION:

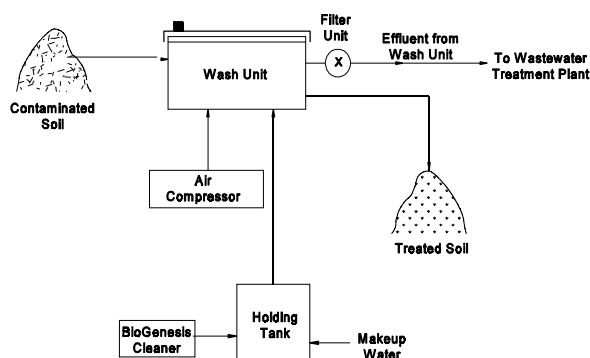
The BioGenesisSM soil and sediment washing process uses specialized, patent-pending equipment, complex surfactants, and water to clean soil, sediment, and sludge contaminated with organic and inorganic constituents. Two types of mobile equipment wash different sizes of particles. A truck-mounted batch unit processes 20 yards per hour, and washes soil particles 10 mesh and larger. A full-scale, mobile, continuous flow unit cleans sand, silt, clay, and sludge particles smaller than 10 mesh at a rate of 20 to 40 yards per hour. Auxiliary equipment includes tanks, dewatering and water treatment equipment, and a bioreactor. Extraction efficiencies per wash cycle range from 85 to 99 percent. High contaminant levels require multiple washes.

The principal components of the process consist of pretreatment equipment for particle sizing, a truck-mounted soil washer for larger particles, a sediment washing unit(s) for fine particles, and water treatment and reconditioning equipment. The BioGenesisSM soil washing system for larger particles consists of a trailer-mounted gondola plumbed for air mixing, water and chemical addition, oil skimming, and liquid drainage (see figure below). Water, BioGenesisSM cleaning

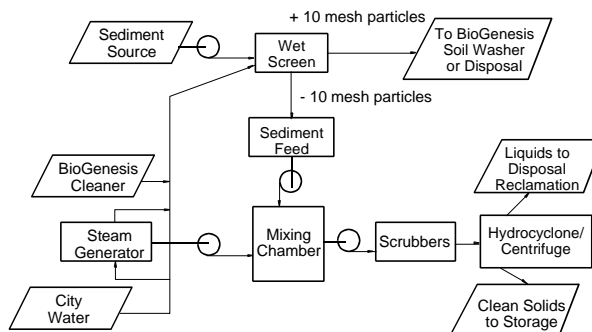
chemicals, and soil are loaded into the gondola. Aeration nozzles feed compressed air to create a fluidized bed. The resulting slurry is agitated to release organic and inorganic contaminants from the soil particles. After mixing, a short settling period allows the soil particles to sink and the removed oil to rise to the water surface, where it is skimmed for reclamation or disposal. Following drainage of the wash water, the treated soil is evacuated by raising the gondola's dump mechanism. Processed soil contains a moisture level of 10 to 20 percent depending on the soil matrix.

A prototype BioGenesisSM sediment washing machine was tested in Environment Canada's Contaminated Sediment Treatment Technology Program. The sediment washing machine is a continuous flow unit. Capacities of up to 80 to 100 cubic yards per hour are possible using full-scale, parallel processing equipment.

In the sediment washing machine, sediment is pretreated to form a slurry. The slurry passes to a shaker screen separator that sizes particles into two streams. Material greater than 1 millimeter (mm) in diameter is diverted to the large particlesoil washer. Material 1 mm and smaller continues to the sediment washer's feed hopper.



Soil Washing Process



Sediment Washing Process

From there, the slurry is injected to the sediment cleaning chamber to loosen the bonds between the pollutant and the particle.

After the cleaning chamber, the slurry flows to the scrubber to further weaken the bonds between contaminants and particles. After the scrubber, the slurry passes through a buffer tank, where large particles separate by gravity. The slurry then flows through hydrocyclone banks to separate solids down to 3 to 5 microns in size. The free liquid routes to a centrifuge for final solid-liquid separation. All solids go to the treated soil pile; all liquid is routed to wastewater treatment to remove organic and inorganic contaminants. Decontaminated wastewater is recycled back through the process. Equipment configuration varies depending on the soil matrix.

The BioGenesis™ cleaning chemical is a light alkaline mixture of ionic and nonionic surfactants and bioremediating agents that act similarly to a biosurfactant. The proprietary cleaner contains no hazardous ingredients.

WASTE APPLICABILITY:

This technology extracts many inorganics, volatile and nonvolatile hydrocarbons, chlorinated hydrocarbons, pesticides, polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons, and most organics from nearly every soil and sediment type, including clay.

STATUS:

The BioGenesisSM soil washing technology was accepted into the SITE Demonstration Program in June 1990. The process was demonstrated in November 1992 on weathered crude oil at a refinery site in Minnesota. Results from the demonstration have been published in the Innovative Technology Evaluation Report (EPA/540/R-93/510) and the SITE Technology Capsule (EPA/540/SR-93/510). The reports are available from EPA. BioGenesis Enterprises, Inc., is planning a future demonstration of the BioGenesisSM sediment washing process using PCB-contaminated sediment.

DEMONSTRATION RESULTS:

Results of the SITE demonstration are presented below:

- Soil washing and biodegradation with BioGenesisSM removed about 85 percent of the total recoverable petroleum hydrocarbon (TRPH)-related contaminants in the soil.
- Treatment system performance was reproducible at constant operating conditions.
- At the end of 90 days, TRPH concentrations decreased an additional 50 percent compared to washing alone.
- The prototype equipment operated within design parameters. New production equipment is expected to streamline overall operating efficiency.

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BIO-REM, INC.

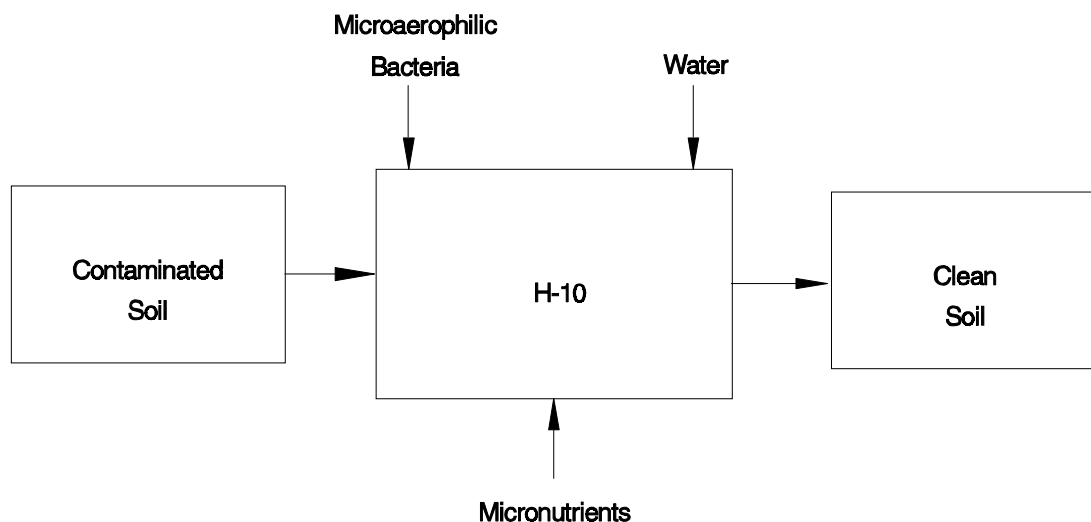
(Augmented In Situ Subsurface Bioremediation Process)

TECHNOLOGY DESCRIPTION:

The Bio-Rem, Inc., Augmented In Situ Subsurface Bioremediation Process uses a proprietary blend (H-10) of microaerophilic bacteria and micronutrients for subsurface bioremediation of hydrocarbon contamination in soil and water (see figure below). The insertion methodology is adaptable to site-specific situations. The bacteria are hardy and can treat contaminants in a wide temperature range. The process does not require additional oxygen or oxygen-producing compounds, such as hydrogen peroxide. Degradation products include carbon dioxide and water.

The bioremediation process consists of four steps: (1) defining and characterizing the contamination plume; (2) selecting a site-specific application methodology; (3) initiating and propagating the bacterial culture; and (4) monitoring and reporting cleanup.

This technology treats soil and water contaminated with hydrocarbons, including halogenated hydrocarbons. Use of the augmented bioremediation process is site-specific, and therefore engineered for each individual site. The success of the process is dependent on a complete and accurate site characterization study. This data is necessary to determine the treatment magnitude and duration.



Augmented In Situ Subsurface Bioremediation Process

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1991. The technology was successfully demonstrated at Williams Air Force Base in Phoenix, Arizona from May 1992 through June 1993. The Demonstration Bulletin (EPA/540/MR-93/527) is available from EPA. Bio-Rem, Inc., has remediated sites throughout the U.S., and in Canada and Central Europe.

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BIOTHERM, LCC
(formerly Dehydro-Tech Corporation)
(Biotherm Process™)

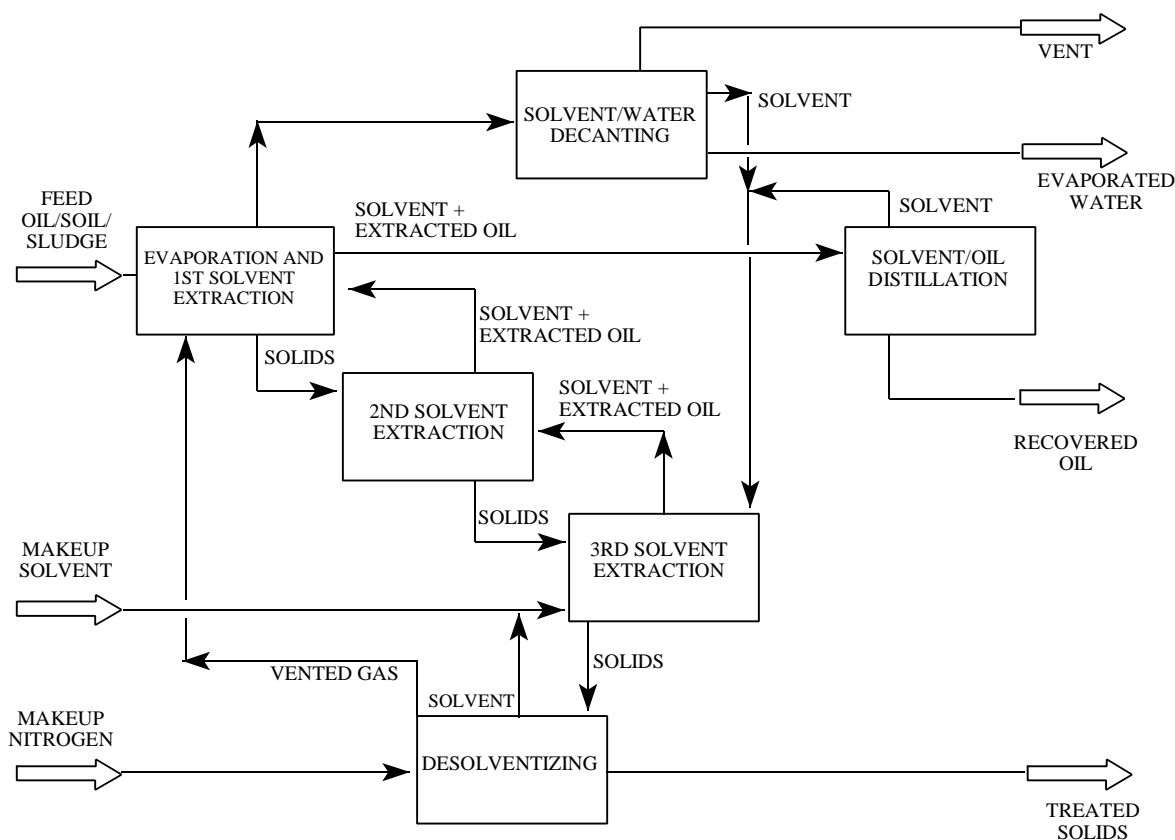
TECHNOLOGY DESCRIPTION:

The Biotherm Process™ combines dehydration and solvent extraction technologies to separate wet, oily wastes into their constituent solid, water, and oil phases (see figure below).

Waste is first mixed with a low-cost hydrocarbon solvent. The resultant slurry mixture is fed to an evaporator system that vaporizes water and initiates solvent extraction of the indigenous oil extraction unit, where solids contact recycled solvent until the target amount of indigenous oil is removed. Depending on the water content of the feed, single-effect or energy-saving multi-effect

evaporators may be used. Next, the slurry of dried solids is treated in a multistage solvent. Finally, solids are centrifuged away from the solvent, followed by "desolventizing," an operation that evaporates residual solvent. The final solids product typically contains less than 2 percent water and less than 1 percent solvent. The spent solvent, which contains the extracted indigenous oil, is distilled to separate the solvent for reuse, and the oil for recovery or disposal.

The Biotherm Process™ yields (1) a clean, dry solid; (2) a water product virtually free of solids, indigenous oil, and solvent; and (3) the extracted indigenous oil, which contains the hazardous hydrocarbon-soluble feed components.



Biotherm Process™ Schematic Diagram

The Biotherm Process™ combination of dehydration and solvent extraction has the following advantages: (1) any emulsions initially present are broken and potential emulsion formation is prevented; (2) solvent extraction is more efficient because water is not present; and (3) the dry solids product is stabilized more readily if required (for example, if metals contamination is a concern).

WASTE APPLICABILITY:

The Biotherm Process™ can treat sludges, soils, sediments, and other water-bearing wastes containing hydrocarbon-soluble hazardous compounds, including polychlorinated biphenyls, polynuclear aromatic hydrocarbons, and dioxins. The process has been commercially applied to municipal wastewater sludge, paper mill sludge, rendering waste, pharmaceutical plant sludge, and other wastes.

STATUS:

The Biotherm Process™ was accepted into the SITE Demonstration Program in 1990. The pilot-scale SITE demonstration of this technology was completed in August 1991 at EPA's research facility in Edison, New Jersey. Spent petroleum drilling fluids from the PAB oil site in Abbeville, Louisiana, were used as process feed. The Applications Analysis Report (EPA/540/AR-92/002), Technology Demonstration Summary (EPA/540/SR-92/002), and Technology Evaluation Report (EPA/540/R-92/002) are available from EPA.

DEMONSTRATION RESULTS:

The SITE demonstration of the Biotherm Process™ yielded the following results:

- The process successfully separated the petroleum-contaminated sludge into its solid, indigenous oil, and water phases. No detectable levels of indigenous total petroleum hydrocarbons were present in the final solid product.

- The final solid product was a dry powder similar to bentonite. A food-grade solvent comprised the bulk of the residual hydrocarbons in the solid.
- Values for all metals and organics were well below the Resource Conservation and Recovery Act toxicity characteristic leaching procedure limits for characteristic hazardous wastes.
- The resulting water product required treatment due to the presence of small amounts of light organics and solvent. Normally, it may be disposed of at a local publicly owned treatment works.
- A full-scale Biotherm Process™ can treat drilling fluid wastes at technology-specific costs of \$100 to \$220 per ton of wet feed, exclusive of disposal costs for the residuals. Site-specific costs, which include the cost of residual disposal, depend on site characteristics and treatment objectives.

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BIOTROL® (Biological Aqueous Treatment System)

TECHNOLOGY DESCRIPTION:

The BioTrol biological aqueous treatment system (BATS) is a patented biological system that treats contaminated groundwater and process water. The system uses naturally occurring microbes; in some instances, however, a specific microorganism may be added. This technique, known as microbial amendment, is important if a highly toxic or recalcitrant target compound is present. The amended microbial system removes both the target contaminant and the background organic carbon.

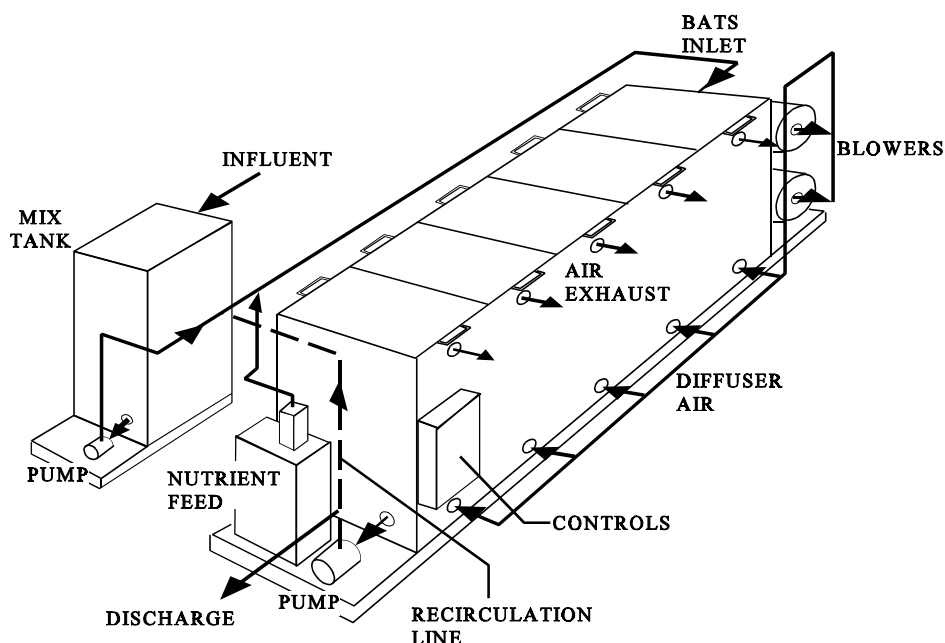
The figure below is a schematic of the BATS. Contaminated water enters a mix tank, where the pH is adjusted and inorganic nutrients are added. If necessary, the water is heated to an optimum temperature with a heater and a heat exchanger, to minimize energy costs. The water then flows to the bioreactor, where the contaminants are biodegraded.

The microorganisms that degrade the contaminants are immobilized in a multiple-cell, submerged, fixed-film bioreactor. Each cell is filled with a highly porous packing material to which the microbes adhere. For aerobic conditions, air is supplied by fine bubble membrane diffusers mounted at the bottom of each cell. The system may also run under anaerobic conditions.

As water flows through the bioreactor, the contaminants are degraded to biological end-products, predominantly carbon dioxide and water. The resulting effluent may be discharged to a publicly owned treatment works or reused on site. In some cases, discharge with a National Pollutant Discharge Elimination System permit may be possible.

WASTE APPLICABILITY:

The BATS may be applied to a wide variety of wastewaters, including groundwater, lagoons, and



BioTrol Biological Aqueous Treatment System (BATS)

process water. Contaminants amenable to treatment include pentachlorophenol (PCP), creosote components, gasoline and fuel oil components, chlorinated hydrocarbons, phenolics, and solvents. Other potential target waste streams include coal tar residues and organic pesticides. The BATS may also be effective for treating certain inorganic compounds such as nitrates; however, this application has not yet been demonstrated. The system does not treat metals.

STATUS:

The BATS was accepted into the SITE Demonstration Program in 1989. The system was demonstrated under the SITE Program from July to September 1989 at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. The system operated continuously for 6 weeks at three different flow rates. The Applications Analysis Report (EPA/540/A5-91/001), the Technology Evaluation Report (EPA/540/5-91/001), and the Demonstration Bulletin (EPA/540/M5-91/001) are available from EPA.

During 1986 and 1987, BioTrol performed a successful 9-month pilot-scale field test of the BATS at a wood preserving facility. Since that time, the firm has installed more than 20 full-scale systems and has performed several pilot-scale demonstrations. These systems have successfully treated waters contaminated with gasoline, mineral spirit solvents, phenol, and creosote.

DEMONSTRATION RESULTS:

For the SITE demonstration, the BATS yielded the following results:

- Reduced PCP concentrations from about 45 parts per million (ppm) to 1 ppm or less in a single pass
- Produced minimal sludge and no PCP air emissions
- Mineralized chlorinated phenolics
- Eliminated groundwater biotoxicity
- Appeared to be unaffected by low concentrations of oil and grease (about 50 ppm) and heavy metals in groundwater
- Required minimal operator attention

The treatment cost per 1,000 gallons was \$3.45 for a 5-gallon-per-minute (gpm) pilot-scale system and \$2.43 for a 30-gpm system.

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BIOTROL® (Soil Washing System)

TECHNOLOGY DESCRIPTION:

The BioTrol Soil Washing System is a patented, water-based volume reduction process used to treat excavated soil. The system may be applied to contaminants concentrated in the fine-sized soil fraction (silt, clay, and soil organic matter) or in the coarse soil fraction (sand and gravel).

In the first part of the process, debris is removed from the soil. The soil is then mixed with water and subjected to various unit operations common to the mineral processing industry (see figure below). The equipment used in these operations can include mixing trommels, pug mills, vibrating screens, froth flotation cells, attrition scrubbing machines, hydrocyclones, screw classifiers, and various dewatering apparatus.

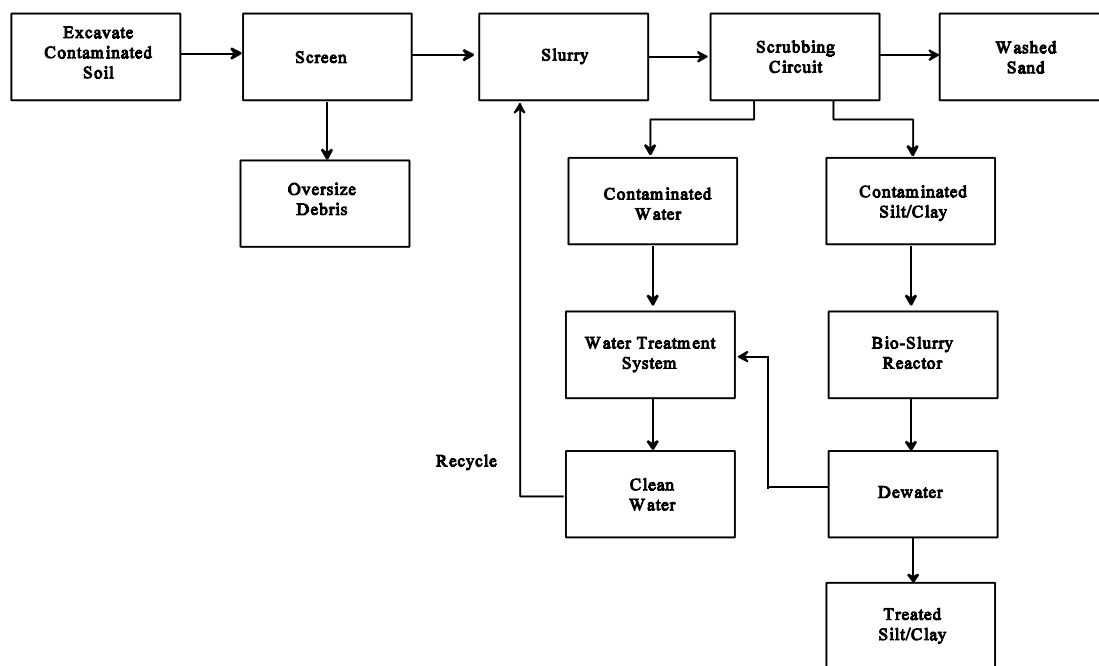
The core of the process is a multistage, counter-current, intensive scrubbing circuit with interstage classification. The scrubbing action disintegrates soil aggregates, freeing contaminated fine particles

from the coarser material. In addition, surficial contamination is removed from the coarse fraction by the abrasive scouring action of the particles themselves. Contaminants may also be solubilized, as dictated by solubility characteristics or partition coefficients.

Contaminated residual products can be treated by other methods. Process water is normally recycled after biological or physical treatment. Contaminated fines may be disposed of off site, incinerated, stabilized, or biologically treated.

WASTE APPLICABILITY:

This system was initially developed to clean soils contaminated with wood preserving wastes, such as polynuclear aromatic hydrocarbons (PAH) and pentachlorophenol (PCP). The system may also apply to soils contaminated with petroleum hydrocarbons, pesticides, polychlorinated biphenyls, various industrial chemicals, and metals.



BioTrol Soil Washing System Process Diagram

STATUS:

The BioTrol Soil Washing System was accepted into the SITE Demonstration Program in 1989. The system was demonstrated under the SITE Program between September and October 1989 at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. A pilot-scale unit with a treatment capacity of 500 pounds per hour operated 24 hours per day during the demonstration. Feed for the first phase of the demonstration (2 days) consisted of soil contaminated with 130 parts per million (ppm) PCP and 247 ppm total PAHs; feed for the second phase (7 days) consisted of soil containing 680 ppm PCP and 404 ppm total PAHs.

Contaminated process water was treated biologically in a fixed-film reactor and recycled. A portion of the contaminated soil fines was treated biologically in a three-stage, pilot-scale EIMCO Biolift™ reactor system supplied by the EIMCO Process Equipment Company. The Applications Analysis Report (EPA/540/A5-91/003) and the Technology Evaluation Report Volume I (EPA/540/5-91/003a) and Volume II (EPA/540/5-91/003b and EPA/540/5-91/003c) are available from EPA.

DEMONSTRATION RESULTS:

Key findings from the BioTrol demonstration are summarized below:

- Feed soil (dry weight basis) was successfully separated into 83 percent washed soil, 10 percent woody residues, and 7 percent fines. The washed soil retained about 10 percent of the feed soil contamination; 90 percent of this contamination was contained within the woody residues, fines, and process wastes.
- The multistage scrubbing circuit removed up to 89 percent PCP and 88 percent total PAHs, based on the difference between concentration levels in the contaminated (wet) feed soil and the washed soil.
- The scrubbing circuit degraded up to 94 percent PCP in the process water during soil washing. PAH removal could not be determined because of low influent concentrations.
- The cost of a commercial-scale soil washing system, assuming use of all three technologies (soil washing, water treatment, and fines treatment), was estimated to be \$168 per ton. Incineration of woody material accounts for 76 percent of the cost.

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BRICE ENVIRONMENTAL SERVICES CORPORATION (Soil Washing Process)

TECHNOLOGY DESCRIPTION:

Brice Environmental Services Corporation (Brice) developed a soil washing process that removes particulate metal contamination from soil. The process has been successfully coupled with acid leaching processes developed by Brice and others for the removal of ionic metal salts and metal coatings from soil. The Brice soil washing process is modular and uses components specifically suited to site soil conditions and cleanup standards. Component requirements and anticipated cleanup levels attainable with the process are determined during treatability testing at Brice's Fairbanks, Alaska facility laboratory. The process is designed to recirculate wash water and leachate solutions.

Particulate metal contaminants removed from soil, and metals recovered from the leaching system (if used), are recycled at a smelting facility. Instead of stabilizing the metals in place or placing the materials in a landfill, the Brice technology removes metal contaminants from the soil, thereby eliminating the health hazard associated with heavy metal contamination.

WASTE APPLICABILITY:

The Brice soil washing process treats soils contaminated with heavy metals. Typical materials suited for treatment with the technology include soils at small arm ranges, ammunition



Brice soil Washing Plant

manufacturing and testing facilities, foundry sites, and sites used for lead-acid battery recycling.

STATUS:

The Brice soil washing process was accepted into the SITE Demonstration Program in winter 1991. Under the program, the technology was demonstrated in late summer 1992 on lead-contaminated soil at the Alaskan Battery Enterprises (ABE) Superfund site in Fairbanks, Alaska. The Demonstration Bulletin (EPA/540/MR-93/503) and the Applications Analysis Report (EPA/540/A5-93/503) are available from EPA.

A Brice soil washing plant was operated in New Brighton, Minnesota for 9 months at Twin Cities Army Ammunition Plant (TCAAP - see photograph) to process 20,000 tons of contaminated soil. The wash plant was used in conjunction with a leaching plant (operated by a separate developer) that removed ionic lead following particulate metal removal.

During Fall 1996, Brice performed a soil washing/soil leaching technology demonstration at a small arms range at Fort Polk, Louisiana. The process implemented physical separation of bullet and bullet fragments from soil particles, and included a leaching step for removing residual ionic lead. A total of 835 tons of soil were processed during this demonstration, and all demonstration goals were met with no soil requiring reprocessing.

In August 1998, Brice completed a full-scale soil washing operation at the Marine Corps Air Ground Combat Center in Twentynine Palms, California. This operation involved processing about 12,000 tons of soil at a small arms firing range.

Several successful demonstrations of the pilot-scale unit have been conducted. The results from the SITE demonstration have been published in a Technology Evaluation Report (EPA/540/5-91/006a), entitled "Design and Development of a Pilot-Scale Debris Decontamination System" and in a Technology Demonstration Summary (EPA/540/S5-91/006).

EPA developed a full-scale unit with ancillary equipment mounted on three 48-foot flatbed semi-trailers. EPA is expecting to formalize a nonexclusive licensing agreement for the equipment in late 1998 to increase the technology's use in treating contaminated debris.

DEMONSTRATION RESULTS:

The demonstration at the ABE site consisted of three test runs of five hours each, with 48 tons of soil processed. Feed soils averaged 4,500 milligrams per kilogram (mg/kg) and the separated soil fines fraction averaged 13,00 mg/kg. On-line reliability was 92 percent, and all processed gravel passed TCLP testing. Battery casing removal efficiencies during the three runs were 94 percent, 100 percent and 90 percent.

The results for the demonstration at the TCAAP site indicated that the Brice technology reduced the lead load to the leaching process from 39 percent to 53 percent. Soil was continuously processed at a rate of 12 to 15 tons per hour.

Results of the Fort Polk demonstration indicate that the technology reduced lead from firing range soils by 97 percent. All soil processed was below the demonstration goals of 500 mg/kg total lead and 5 milligrams per liter (mg/L) TCLP lead. Average results for all processed soil were 156 mg/kg total lead and 2.1 mg/L TCLP lead. Processing rates ranged from 6 to 12 tons per hour.

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BWX TECHNOLOGIES, INC.
(an affiliate of BABCOCK & WILCOX CO.)
(Cyclone Furnace)

TECHNOLOGY DESCRIPTION:

The Babcock & Wilcox Co. (Babcock & Wilcox) cyclone furnace is designed to combust coal with high inorganic content (high-ash). Through cofiring, the cyclone furnace can also accommodate highly contaminated wastes containing heavy metals and organics in soil or sludge. High heat-release rates of 45,000 British thermal units (Btu) per cubic foot of coal and high turbulence in cyclones ensures the high temperatures required for melting the high-ash fuels and combusting the organics. The inert ash exits the cyclone furnace as a vitrified slag.

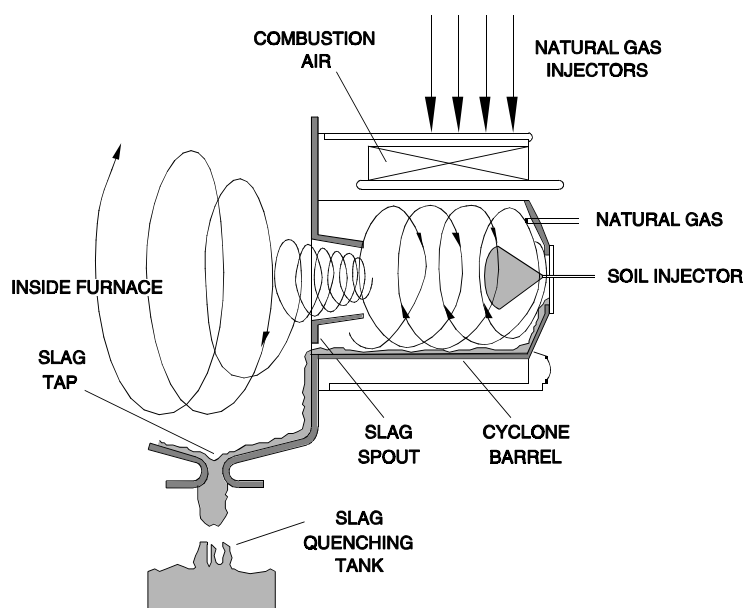
The pilot-scale cyclone furnace, shown in the figure below, is a water cooled, scaled-down version of a commercial coal-fired cyclone with a restricted exit (throat). The furnace geometry is a horizontal cylinder (barrel).

Natural gas and preheated combustion air are heated to 820 °F and enter tangentially into the

cyclone burner. For dry soil processing, the soil matrix and natural gas enter tangentially along the cyclone furnace barrel. For wet soil processing, an atomizer uses compressed air to spray the soil slurry directly into the furnace. The soil or sludge and inorganics are captured and melted, and organics are destroyed in the gas phase or in the molten slag layer. This slag layer is formed and retained on the furnace barrel wall by centrifugal action.

The soil melts, exits the cyclone furnace from the tap at the cyclone throat, and drops into a water-filled slag tank where it solidifies. A small quantity of soil also exits as fly ash with the flue gas from the furnace and is collected in a baghouse. In principle, this fly ash can be recycled to the furnace to increase metal capture and to minimize the volume of the potentially hazardous waste stream.

The energy requirements for vitrification are 15,000 Btu per pound of soil treated. The cyclone



Cyclone Furnace

furnace can be operated with gas, oil, or coal as the supplemental fuel. If the waste is high in organic content, it may also supply a significant portion of the required fuel heat input.

Particulates are captured by a baghouse. To maximize the capture of particulate metals, a heat exchanger is used to cool the stack gases to approximately 200 °F before they enter the baghouse.

WASTE APPLICABILITY:

The cyclone furnace can treat highly contaminated hazardous wastes, sludges, and soils that contain heavy metals and organic constituents. The wastes may be solid, a soil slurry (wet soil), or liquids. To be treated in the cyclone furnace, the ash or solid matrix must melt (with or without additives) and flow at cyclone furnace temperatures (2,400 to 3,000 °F). Because the furnace captures heavy metals in the slag and renders them nonleachable, it is particularly suited to soils that contain lower-volatility radionuclides such as strontium and transuranics.

Based on results from the Emerging Technology Program, the cyclone furnace technology was accepted into the SITE Demonstration Program in August 1991. A demonstration occurred in November 1991 at the developer's facility in Alliance, Ohio. The process was demonstrated using an EPA-supplied, wet synthetic soil matrix (SSM) spiked with heavy metals (lead, cadmium, and chromium), organics (anthracene and dimethylphthalate), and simulated radionuclides (bismuth, strontium, and zirconium). Results from the demonstrations have been published in the Applications Analysis Report (EPA/520/AR-92/017) and Technology Evaluation Report, Volumes 1 and 2 (EPA/504/R-92/017A and EPA/540/R-92/017B); these documents are available from EPA.

DEMONSTRATION RESULTS:

Vitrified slag leachabilities for the heavy metals met EPA toxicity characteristic leaching procedure (TCLP) limits. TCLP leachabilities were 0.29 milligram per liter (mg/L) for lead, 0.12 mg/L for cadmium, and 0.30 mg/L for chromium. Almost 95 percent of the noncombustible SSM was incorporated into the slag. Greater than 75 percent of the chromium, 88 percent of the strontium, and 97 percent of the zirconium were captured in the slag. Dry weight volume was reduced 28 percent. Destruction and removal efficiencies for anthracene and dimethylphthalate were greater than 99.997 percent and 99.998 percent, respectively. Stack particulates were 0.001 grain per dry standard cubic foot (gr/dscf) at 7 percent oxygen, which was below the Resource Conservation Recovery Act limit of 0.08 gr/dscf effective until May 1993. Carbon monoxide and total hydrocarbons in the flue gas were 6.0 parts per million (ppm) and 8.3 ppm, respectively.

An independent cost analysis was performed as part of the SITE demonstration. The cost to remediate 20,000 tons of contaminated soil using a 3.3-ton-per-hour unit was estimated at \$465 per ton if the unit is on line 80 percent of the time, and \$529 per ton if the unit is on line 60 percent of the time.

FOR FURTHER INFORMATION:

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CALGON CARBON ADVANCED OXIDATION TECHNOLOGIES (formerly VULCAN PEROXIDATION SYSTEMS, INC.) (perox-pure™ Chemical Oxidation Technology)

TECHNOLOGY DESCRIPTION:

The **perox-pure™** treatment system is designed to destroy dissolved organic contaminants in groundwater or wastewater with an advanced chemical oxidation process that uses ultraviolet (UV) radiation and hydrogen peroxide.

In the process, proprietary high-powered, medium-pressure lamps emit high-energy UV radiation through a quartz sleeve into the contaminated water. Hydrogen peroxide is added to the contaminated water and is activated by the UV light to form oxidizing species called hydroxyl radicals:



The hydroxyl radical then reacts with the dissolved contaminants, initiating a rapid cascade of oxidation reactions that ultimately fully oxidize (mineralize) the contaminants. The success of the process is based on the fact that the rate constants

for the reaction of $\cdot\text{OH}$ radicals with most organic pollutants are very high. The hydroxyl radical typically reacts a million to a billion times faster than chemical oxidants such as ozone and hydrogen peroxide. In addition, many organic contaminants (e.g. PCE) undergo a change in their chemical structure by the direct absorption of UV light in the UV-C spectral range emitted by Calgon Carbon Corporation's proprietary medium-pressure UV lamps.

WASTE APPLICABILITY:

The **perox-pure™** technology treats groundwater and wastewater contaminated with chlorinated solvents, pesticides, polychlorinated biphenyls, phenolics, ethers, fuel hydrocarbons, and other organic compounds. It is effective on concentrations ranging from low parts per billion to several hundred parts per million (ppm). In certain instances, when used in conjunction with photocatalysts, it can be competitive for contaminated waters at concentrations of several



perox-pure™ Model SSB-30

thousand parts per million (ppm). In some cases, the combination of the **perox-pure**TM technology with activated carbon, air stripping, or biological treatment will provide a more economical approach than would be obtained by using only one technology.

STATUS:

The **perox-pure**TM technology was accepted into the SITE Demonstration Program in April 1991. A Model SSB-30 (see photograph on previous page) was demonstrated in September 1992 at the Lawrence Livermore National Laboratory Superfund site in Altamont Hills, California. The purpose of this demonstration was to measure how well the **perox-pure**TM technology removed volatile organic compounds from contaminated groundwater at the site. The Demonstration Bulletin (EPA/540/MR-93/501), Technology Demonstration Summary (EPA/540/SR-93/501), Applications Analysis Report (EPA/540/AR-93/501), and Technology Evaluation Report (EPA/540/R-93/501) are available from EPA.

This technology has been successfully applied to over 250 sites throughout the United States, Canada, the Far East, and Europe. The treatment units at these sites have treated contaminated groundwater, industrial wastewater, contaminated drinking water, landfill leachates, and industrial reuse streams (process waters). Equipment treatment rates range from several gallons to several thousand gallons per minute.

DEMONSTRATION RESULTS:

Operating parameters for the treatment system were varied during the demonstration. Three

reproducibility tests were performed at the optimum operating conditions, which were selected from the initial test runs.

In most cases, the **perox-pure**TM technology reduced trichloroethene, tetrachloroethene, chloroform, trichloroethane, and dichloroethane to below analytical detection limits. For each organic contaminant, the **perox-pure**TM technology complied with California action levels and federal drinking water maximum contaminant levels at the 95 percent confidence level. The quartz sleeve wipers effectively cleaned the sleeves and eliminated the interference caused by tube scaling.

FOR FURTHER INFORMATION:

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CF SYSTEMS CORPORATION (Liquified Gas Solvent Extraction [LG-SX] Technology)

TECHNOLOGY DESCRIPTION:

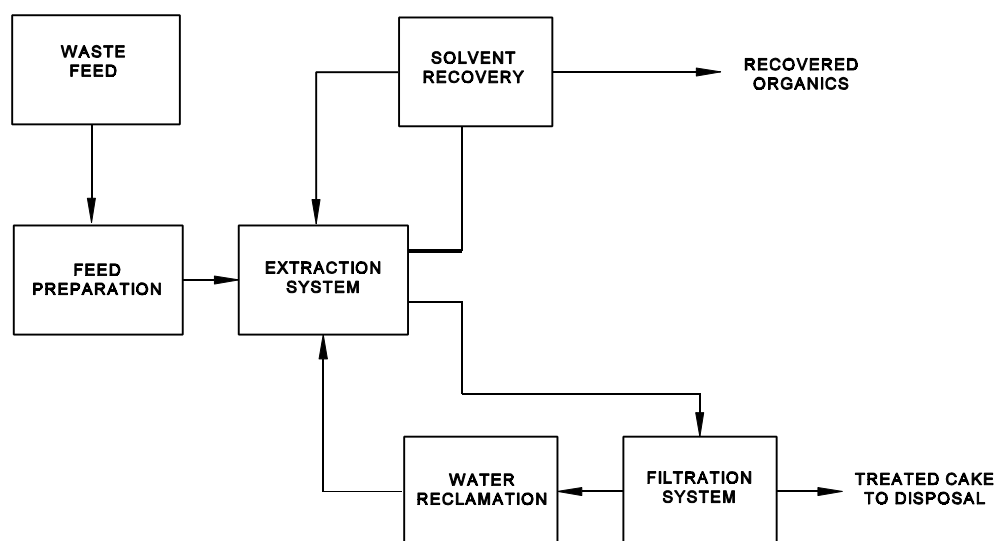
The CF Systems Corporation (CF Systems) liquified gas solvent extraction (LG-SX) technology uses liquified gas solvents to extract organics from soils, sludges, sediments, and wastewaters. Gases, when liquified under pressure, have unique physical properties that enhance their use as solvents. The low viscosities, densities, and surface tensions of these gases result in significantly higher rates of extraction compared to conventional liquid solvents. These enhanced physical properties also accelerate treated water's gravity settling rate following extraction. Due to their high volatility, gases are also easily recovered from the suspended solids matrix, minimizing solvent losses.

Liquified propane solvent is typically used to treat soils, sludges, and sediments, while liquified carbon dioxide is typically used to treat wastewater. The extraction system uses a batch extractor-decanter design for solids and sludges and a continuous trayed tower design for wastewaters and low-solids wastes.

Contaminated solids, slurries, or wastewaters are fed into the extraction system along with solvent (see figure below). After the solvent and organics are separated from the treated feed, the solvent and organic mixture passes to the solvent recovery system. Once in the solvent recovery system, the solvent is vaporized and recycled as fresh solvent. The organics are drawn off and either reused or disposed of. Treated feed is discharged from the extraction system as a slurry. The slurry is filtered and dewatered. The reclaimed water is recycled to the extraction system and the filter cake is sent for disposal or reused.

WASTE APPLICABILITY:

The LG-SX technology can be applied to soils and sludges containing volatile and semivolatile organic compounds and other higher boiling point complex organics, such as polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), dioxins, and pentachlorophenol (PCP). This process can also treat refinery wastes and wastewater contaminated with organics.



Liquified Gas Solvent Extraction (LG-SX) Technology

STATUS:

This technology was accepted into the SITE Demonstration Program in 1988. Under the SITE Program, a pilot-scale mobile demonstration unit was tested in September 1988 on PCB-laden sediments from the New Bedford Harbor Superfund site in Massachusetts. PCB concentrations in the harbor sediment ranged from 300 parts per million (ppm) to 2,500 ppm. The Technology Evaluation Report (EPA/540/5-90/002) and the Applications Analysis Report (EPA/540/A5-90/002) are available from EPA.

A pilot-scale treatability study was completed on PCB-contaminated soil from a Michigan Superfund site. Analytical data showed that the treatment reduced PCB levels to below 5 parts per million (ppm), representing a 98 percent removal efficiency for this waste. A Project Summary (EPA/540/SR-95/505), which details results from this work, is available from EPA.

CF Systems completed the first commercial on-site treatment operation at Star Enterprise in Port Arthur, Texas. The propane-based solvent extraction unit processed listed refinery K- and F-wastes, producing Resource Conservation and Recovery Act treated solids that met EPA land-ban requirements. The unit operated continuously from March 1991 to March 1992 and was on-line more than 90 percent of the time. Following heavy metals fixation, the treated solids were disposed of in a Class I landfill.

Effective mid-1998, Morrison Knudsen Corporation, owner of CF Environmental Corporation, has terminated research and development of the LG-SX program, and no longer actively markets the technology.

DEMONSTRATION RESULTS:

This technology was demonstrated concurrently with dredging studies managed by the U.S. Army

Corps of Engineers. Contaminated sediments were treated by the LG-SX technology, using a liquified propane and butane mixture as the extraction solvent. The demonstration at the New Bedford site yielded the following results:

- Extraction efficiencies were 90 to 98 percent for sediments containing PCBs between 360 and 2,575 ppm. PCB concentrations were as low as 8 ppm in the treated sediment.
- Volatile and semivolatile organics in aqueous and semisolid wastes were extracted with 99.9 percent efficiency.
- Operating problems included solids retention in the system hardware and foaming in receiving tanks. The problems were corrected in the full-scale operations at Star Enterprise.
- Projected costs for PCB cleanup were estimated at \$150 to \$450 per ton, including material handling and pre- and posttreatment costs. These costs are highly dependent on the utilization factor and job size, which may result in lower costs for large cleanups.

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CHEMFIX TECHNOLOGIES, INC.
(Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

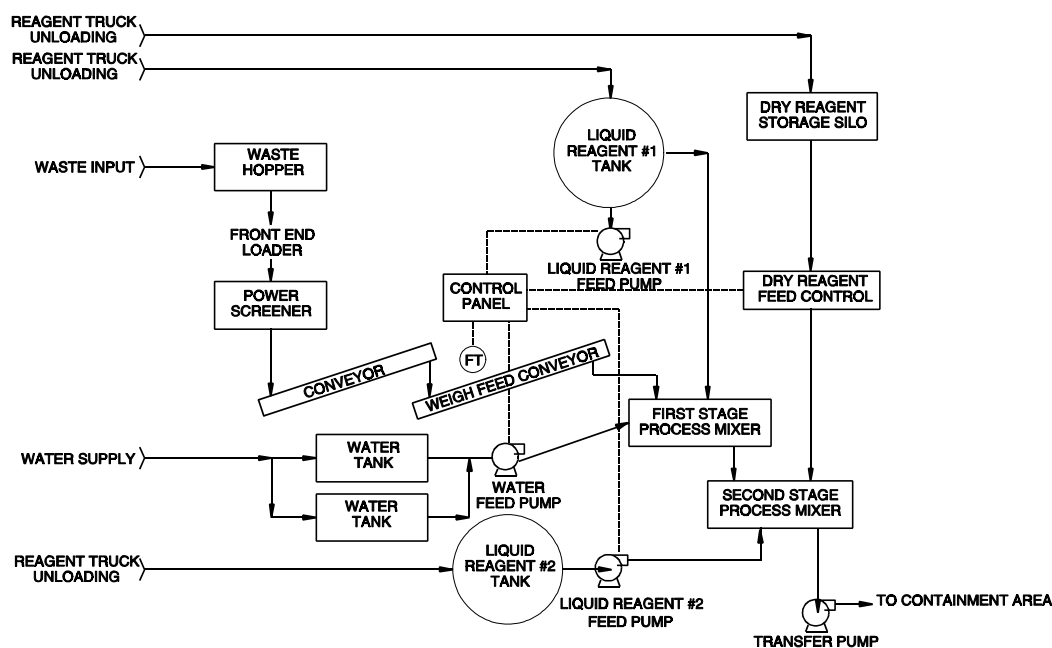
In this solidification and stabilization process, pozzolanic materials react with polyvalent metal ions and other waste components to produce a chemically and physically stable solid material. Optional binders and reagents may include soluble silicates, carbonates, phosphates, and borates. The end product may be similar to a clay-like soil, depending on the characteristics of the raw waste and the properties desired in the end product.

The figure below illustrates the Chemfix Technologies, Inc. (Chemfix), process. Typically, the waste is first blended in a reaction vessel with pozzolanic materials that contain calcium hydroxide. This blend is then dispersed throughout an aqueous phase. The reagents react with one another and with toxic metal ions, forming both anionic and cationic metal complexes. Pozzolans that accelerate and other reagents that precipitate metals can be added before or after the dry binder is initially mixed with the waste.

When a water soluble silicate reacts with the waste and the pozzolanic binder system, colloidal silicate gel strengths are increased within the binder-waste matrix, helping to bind polyvalent metal cations. A large percentage of the heavy metals become part of the calcium silicate and aluminate colloidal structures formed by the pozzolans and calcium hydroxide. Some of the metals, such as lead, adsorb to the surface of the pozzolanic structures. The entire pozzolanic matrix, when physically cured, decreases toxic metal mobility by reducing the incursion of leaching liquids into and out of the stabilized matrices.

WASTE APPLICABILITY:

This process is suitable for contaminated soils, sludges, ashes, and other solid wastes. The process is particularly applicable to electroplating sludges, electric arc furnace dust, heavy metal contaminated soils, oil field drilling muds and cuttings, municipal sewage sludges, and residuals from other treatment processes. This process effectively treats heavy metals, such as antimony, arsenic, lead, cadmium, hexavalent chromium.



Process Flow Diagram

mercury, copper, and zinc. In addition, when combined with specialized binders and additives, this process can stabilize low-level nuclear wastes. With modifications, the system may be applied to wastes containing between 10 to 100 percent solids.

STATUS:

The solidification and stabilization process was accepted into the SITE Demonstration Program in 1988. The process was demonstrated in March 1989 at the Portable Equipment Salvage Company site in Clackamas, Oregon. The Technology Evaluation Report (EPA/540/5-89/011a) and the Applications Analysis Report (EPA/540/A5-89/011) are available from EPA.

In addition, several full-scale remediation projects have been completed since 1977, including a 1991 high solids CHEMSET® reagent protocol designed by Chemfix to treat 30,000 cubic yards of hexavalent chromium-contaminated, high solids waste. The average chromium level after treatment was less than 0.15 milligram per liter and met toxicity characteristic leaching procedure (TCLP) criteria. The final product permeability was less than 1×10^{-6} centimeters per second (cm/sec).

DEMONSTRATION RESULTS:

The demonstration yielded the following results:

- The technology effectively reduced copper and lead concentrations in the wastes. The concentrations in the TCLP extracts from the treated wastes were 94 to 99 percent less than those from the untreated wastes. Total lead concentrations in the untreated waste approached 14 percent.

- The volume of excavated waste material increased between 20 and 50 percent after treatment.
- During the durability tests, the treated wastes showed little or no weight loss after 12 cycles of wetting and drying or freezing and thawing.
- The unconfined compressive strength of the wastes varied between 27 and 307 pounds per square inch after 28 days. Hydraulic conductivity of the treated material ranged between 1×10^{-6} cm/sec and 6.4×10^{-7} cm/sec.
- Air monitoring data suggest there was no significant volatilization of polychlorinated biphenyls during the treatment process.
- Treatment costs were approximately \$73 per ton, including mobilization, labor, reagents, and demobilization, but not disposal.

FOR FURTHER INFORMATION:

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COGNIS, INC. (TERRAMET® Soil Remediation System)

TECHNOLOGY DESCRIPTION:

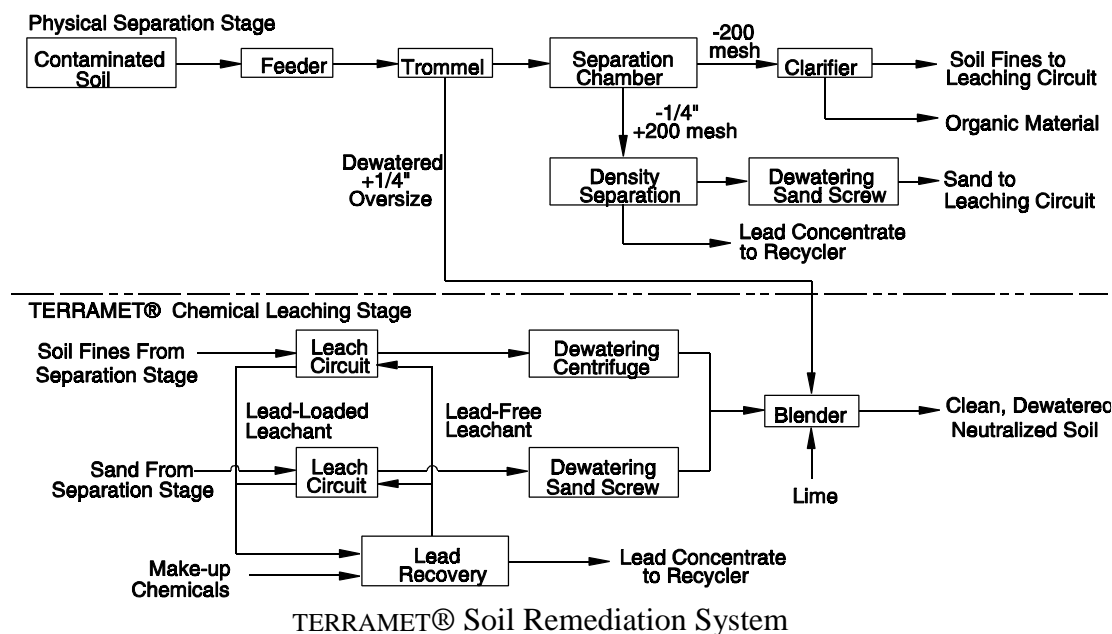
The COGNIS, Inc. (COGNIS), TERRAMET® soil remediation system leaches and recovers lead and other metals from contaminated soil, dust, sludge, or sediment. The system uses a patented aqueous leachant that is optimized through treatability tests for the soil and the target contaminant. The TERRAMET® system can treat most types of lead contamination, including metallic lead and lead salts and oxides. The lead compounds are often tightly bound by fine soil constituents such as clay, manganese and iron oxides, and humus.

The figure below illustrates the process. A pretreatment, physical separation stage may involve dry screening to remove gross oversized material. The soil can be separated into oversized (gravel), sand, and fine (silt, clay, and humus) fractions. Soil, including the oversized fraction, is first washed. Most lead contamination is typically associated with fines fraction, and this fraction is subjected to countercurrent leaching to dissolve the adsorbed lead and other heavy metal species. The sand fraction may also contain significant lead, especially if the contamination is due to particulate lead, such as that found in

battery recycling, ammunition burning, and scrap yard activities. In this case, the sand fraction is pretreated to remove dense metallic or magnetic materials before subjecting the sand fraction to countercurrent leaching. Sand and fines can be treated in separate parallel streams.

After dissolution of the lead and other heavy metal contaminants, the metal ions are recovered from the aqueous leachate by a metal recovery process such as reduction, liquid ion exchange, resin ion exchange, or precipitation. The metal recovery technique depends on the metals to be recovered and the leachant employed. In most cases, a patented reduction process is used so that the metals are recovered in a compact form suitable for recycling. After the metals are recovered, the leachant can be reused within the TERRAMET® system for continued leaching.

Important characteristics of the TERRAMET® leaching/recovery combination are as follows:
(1) the leachant is tailored to the substrate and the contaminant; (2) the leachant is fully recycled within the treatment plant; (3) treated soil can be returned on site; (4) all soil fractions can be treated; (5) end products include treated soil and recycled



metal; and (6) no waste is generated during processing.

WASTE APPLICABILITY:

The COGNIS TERRAMET® soil remediation system can treat soil, sediment, and sludge contaminated by lead and other heavy metals or metal mixtures. Appropriate sites include contaminated ammunition testing areas, firing ranges, battery recycling centers, scrap yards, metal plating shops, and chemical manufacturers. Certain lead compounds, such as lead sulfide, are not amenable to treatment because of their exceedingly low solubilities. The system can be modified to leach and recover other metals, such as cadmium, zinc, copper, and mercury, from soils.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in August 1992. Based on results from the Emerging Technology Program, the technology was accepted into the SITE Demonstration Program in 1994. The demonstration took place at the Twin Cities Army Ammunition Plant (TCAAP) Site F during August 1994. The TERRAMET® system was evaluated during a full-scale remediation conducted by COGNIS at TCAAP. The full-scale system was linked with a soil washing process developed by Brice Environmental Services Corporation (BESCOP). The system treated soil at a rate of 12 to 15 tons per hour. An Innovative Technology Evaluation Report describing the demonstration and its results will be available in 1998.

The TERRAMET® system is now available through Doe Run, Inc. (see contact information below). For further information about the development of the system, contact the Dr. William Fristad (see contact information below). For further information on the BESCOP soil washing process, refer to the profile in the Demonstration Program section (completed projects).

DEMONSTRATION RESULTS:

Lead levels in the feed soil ranged from 380 to 1,800 milligrams per kilogram (mg/kg). Lead

levels in untreated and treated fines ranged from 210 to 780 mg/kg and from 50 to 190 mg/kg, respectively. Average removal efficiencies for lead were about 75 percent. The TERRAMET® and BESCOP processes operated smoothly at a feed rate of 12 to 15 tons per hour. Size separation using the BESCOP process proved to be effective and reduced the lead load to the TERRAMET® leaching process by 39 to 63 percent. Leaching solution was recycled, and lead concentrates were delivered to a lead smelting facility. The cost of treating contaminated soil at the TCAAP site using the COGNIS and BESCOP processes is about \$200 per ton of treated soil, based on treatment of 10,000 tons of soil. This cost includes the cost of removing ordnance from the soil.

FOR FURTHER INFORMATION:

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COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT (developed by COLORADO SCHOOL OF MINES) (Constructed Wetlands-Based Treatment)

TECHNOLOGY DESCRIPTION:

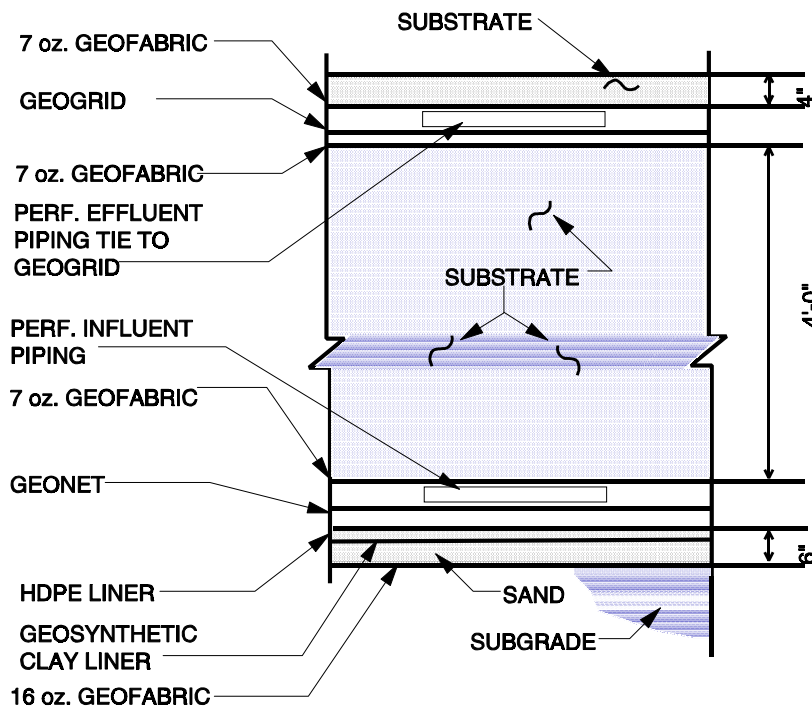
The constructed wetlands-based treatment technology uses natural geochemical and microbiological processes inherent in an artificial wetland ecosystem to accumulate and remove metals from influent waters. The treatment system incorporates principal ecosystem components found in wetlands, such as organic materials (substrate), microbial fauna, and algae.

Influent waters with high metal concentrations flow through the aerobic and anaerobic zones of the wetland ecosystem. Metals are removed by ion exchange, adsorption, absorption, and precipitation through geochemical and microbial oxidation and reduction. Ion exchange occurs as metals in the water contact humic or other organic substances in the soil medium. Oxidation and reduction

reactions that occur in the aerobic and anaerobic zones, respectively, precipitate metals as hydroxides and sulfides. Precipitated and adsorbed metals settle in quiescent ponds or are filtered out as the water percolates through the soil or substrate.

WASTE APPLICABILITY:

The constructed wetlands-based treatment process is suitable for acid mine drainage from metal or coal mining activities. These wastes typically contain high concentrations of metals and low pH. Wetlands treatment has been applied with some success to wastewater in the eastern United States. The process may have to be adjusted to account for differences in geology, terrain, trace metal composition, and climate in the metal mining regions of the western United States.



Schematic Cross Section of Pilot-Scale Upflow Cell

STATUS:

Based on the results of tests conducted during the SITE Emerging Technology Program (ETP), the constructed wetlands-based treatment process was selected for the SITE Demonstration Program in 1991. Results from the ETP tests indicated an average removal rate of 50 percent for metals. For further information on the ETP evaluation, refer to the Emerging Technology Summary (EPA/540/SR-93/523), the Emerging Technology Report (EPA/540/R-93/523), or the Emerging Technology Bulletin (EPA/540/F-92/001), which are available from EPA.

DEMONSTRATION RESULTS:

Studies under the Demonstration Program evaluated process effectiveness, toxicity reduction, and biogeochemical processes at the Burleigh Tunnel, near Silver Plume, Colorado. Treatment of mine discharge from the Burleigh Tunnel is part of the remedy for the Clear Creek/Central City Superfund site. Construction of a pilot-scale treatment system began in summer 1993 and was completed in November 1993. The pilot-scale treatment system covered about 4,200 square feet and consisted of an upflow cell (see figure on previous page) and a downflow cell. Each cell treats about 7 gallons per minute of flow. Preliminary results indicated high removal efficiency (between 80 to 90 percent) for zinc, the primary contaminant in the discharge during summer operation. Zinc removal during the first winter of operation ranged from 60 to 80 percent.

Removal efficiency of dissolved zinc for the upflow cell between March and September remained above 90 percent; however, the removal efficiency between September and December 1994 declined to 84 percent due to the reduction in microbial activity in the winter months. The removal efficiency in the downflow cell dropped to 68 percent in the winter months and was between 70 and 80 percent during the summer months. The 1995 removal efficiency of dissolved zinc for the upflow cell declined from 84 percent to below 50 percent due to substrate hydrologic problems originating from

attempts to insulate this unit during the summer months. A dramatic upset event in the spring of 1995 sent about four times the design flow through the upflow cell, along with a heavy zinc load. The heavy zinc load was toxic to the upflow cell and it never recovered to previous performance levels. Since the upset event, removal efficiency remained at or near 50 percent.

The 1995 removal efficiency of the downflow cell declined from 80 percent during the summer months to 63 percent during winter, again a result of reduced microbial activity. The 1996 removal efficiency of dissolved zinc calculated for the downflow cell increased from a January low of 63 percent to over 95 percent from May through August. The increase in the downflow removal efficiency is related to reduced flow rates through the downflow substrate, translating to increased residence time.

The SITE demonstration was completed in mid-1998, and the cells were decommissioned in August 1998. An Innovative Technology Evaluation Report for the demonstration will be available in 1999. Information on the technology can be obtained through below-listed sources.

FOR FURTHER INFORMATION:

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COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT (developed by COLORADO SCHOOL OF MINES) (Constructed Wetlands-Based Treatment)

TECHNOLOGY DESCRIPTION:

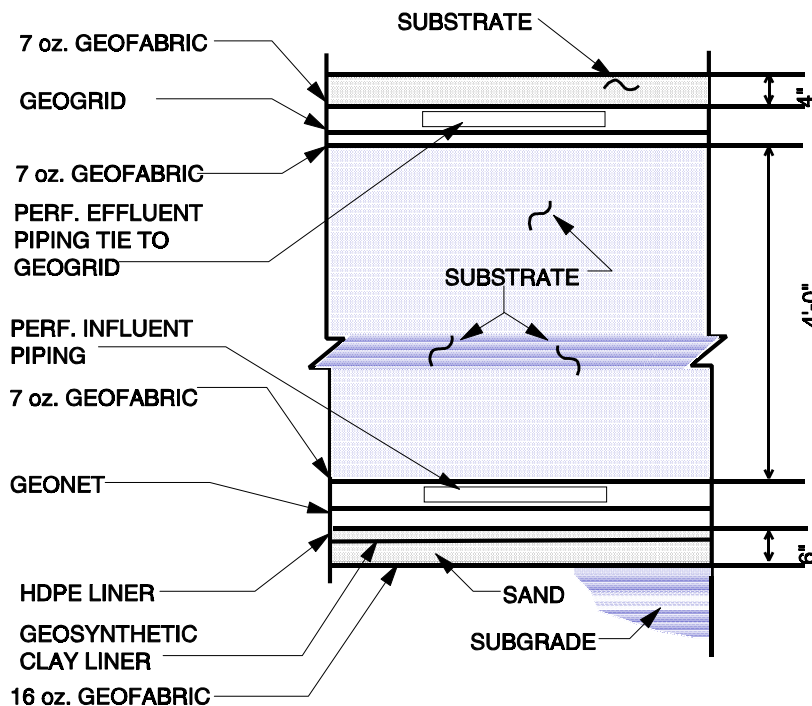
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FOR FURTHER INFORMATION:

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COMMODORE APPLIED TECHNOLOGIES, INC. (Solvated Electron Technology, SET™ Remediation System)

TECHNOLOGY DESCRIPTION:

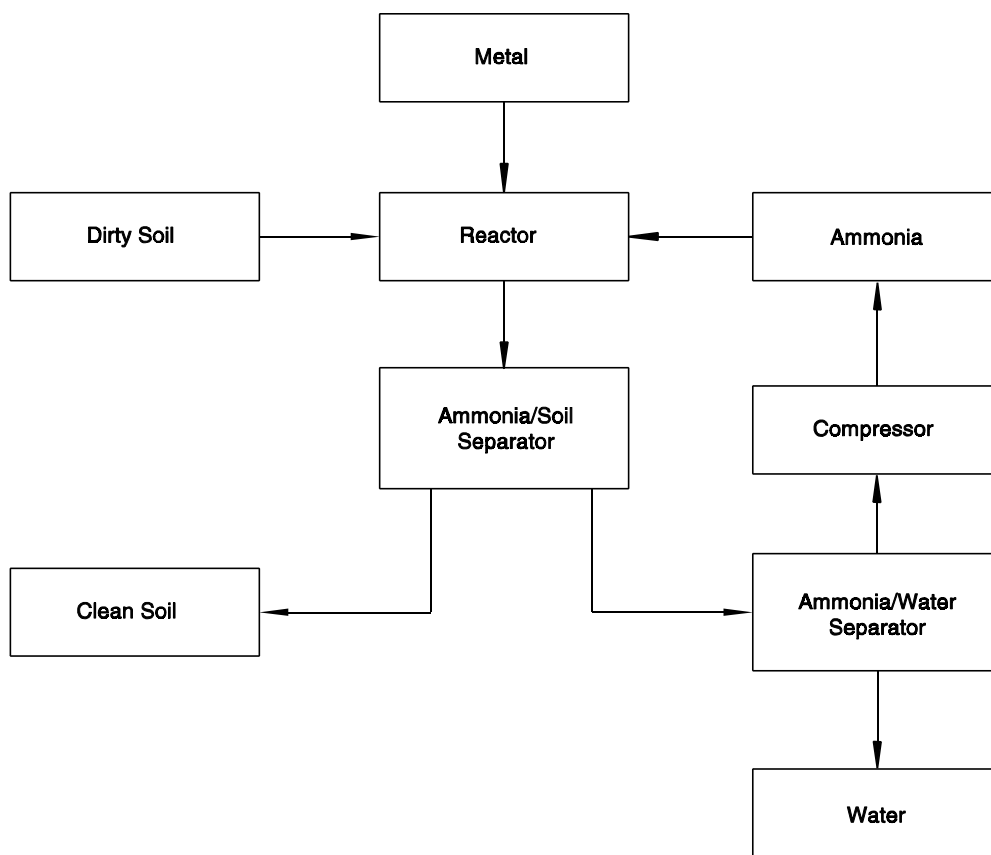
Commodore Applied Technologies, Inc.'s (Commodore), solvated electron technology (SET™) remediation system chemically reduces toxic contaminants such as polychlorinated biphenyls (PCB), pesticides, and other halogenated compounds into benign substances. The solvating system uses a solution of ammonia and an "active" metal to create a powerful reducing agent that can clean up contaminated soils, sediments, and liquids.

A solvated electron solution is a liquid homogeneous mixture that produces a large supply of free electrons. It can be created by combining liquid ammonia with a metal such as sodium, calcium, lithium, or potassium. When a solvated

electron solution is mixed with a contaminated material, the free electrons in the solution chemically convert the contaminant to relatively harmless substances and salts.

The SET™ process consists of components to move and recover the ammonia (such as piping, pumps, and tanks), along with reactor vessels which hold the contaminated medium and the solvating solution. The system can be transported to different field sites, but the process is performed ex situ, meaning that the contaminated medium must be introduced into the reactor vessels.

The treatment process begins by placing the contaminated medium into the reactor vessels, where the medium is then mixed with ammonia.



Schematic Diagram of the Solvated Electron Remediation System

One of the reactive metals (usually sodium) is then added to the contaminated medium-ammonia mixture, and a chemical reaction ensues. After the chemical reaction is complete (about 1 minute), the ammonia is removed to a discharge tank for reuse. The treated medium is then removed from the reactor vessels, tested for contamination, and returned to the site.

WASTE APPLICABILITY:

Commodore claims that its solvating electron remediation system can effectively decontaminate soils, sludges, sediments, oils, hand tools, and personal protective clothing. The technology chemically transforms PCBs, pesticides, and other halogenated compounds into relatively benign salts. Commodore also believes that the technology is effective in treating chemical warfare agents and radionuclides.

STATUS:

Commodore was accepted into the SITE Demonstration Program in 1995 and is also participating in the Rapid Commercialization Initiative (RCI). RCI was created by the Department of Commerce, Department of Defense, Department of Energy, and EPA to assist in the integration of innovative technologies into the marketplace.

Commodore demonstrated the solvating system at the Construction Battalion Supply Center in Port Hueneme, California in September 1996. The demonstration was designed to evaluate the system's performance capability, costs, and design

parameters. Results from the demonstration will be presented in an Innovative Technology Evaluation Report, which is available from EPA.

In October 1997, Commodore was awarded a contract to remediate mixed waste material at the U.S. Department of Energy site at Weldon Spring, Missouri using the SETTM technology.

A nationwide permit for the destruction of PCBs and metals in soils was issued for the SETTM process by the EPA in March, 1997. This permit was amended in May 1998 to include the destruction of PCBs in oil.

FOR FURTHER INFORMATION:

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CURE INTERNATIONAL, INC. (CURE®-Electrocoagulation Wastewater Treatment System)

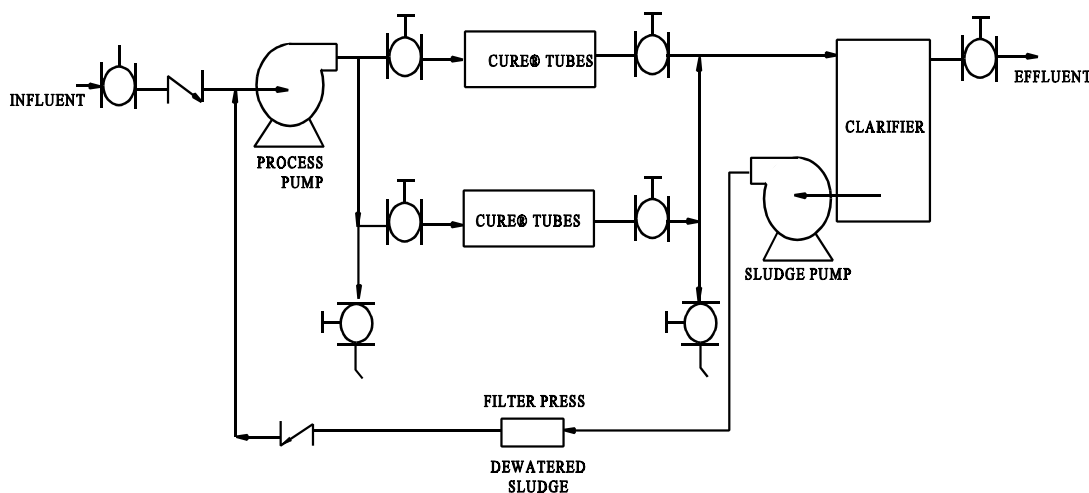
TECHNOLOGY DESCRIPTION:

The CURE® - Electrocoagulation (CURE®) system is designed to remove ionic metal species and other charged particles from water (see figure below). Because many toxic metal ions such as nickel, lead, and chromates are held in solution by electrical charges, they will precipitate out of solution if they are neutralized with oppositely charged ions. The CURE® system is effective at breaking oily emulsions and removing suspended solids. The system improves on previous electrocoagulation methods through a unique geometrical configuration.

The CURE® system's patented geometry maximizes liquid surface contact between the anode and concentric cathode electrocoagulation tubes, thus minimizing the power requirements for efficient operation. The CURE® system allows the

contaminated water to flow continuously through the cathode tube, enabling a direct current to pass uniformly through a water system. The contaminated water then passes through the annular space between the cathode and anode tubes and is exposed to sequential positive and negative electrical fields. Typical retention time is less than 20 seconds. Water characteristics such as pH, oxidation-reduction potential, and conductivity can be adjusted to achieve maximum removal efficiencies for specific contaminants.

After the treated water exits the electrocoagulation tubes, the destabilized colloids are allowed to flocculate and are then separated with an integrated clarifier system. Polymers can be added to enhance flocculation, but in most cases they are not required. The sludge produced by this process is usually very stable and acid-resistant. Tests have shown that sludges produced by the CURE®



CURE®-Electrocoagulation System

system pass the toxicity characteristic leaching procedure (TCLP) and are often disposed of as nonhazardous waste.

WASTE APPLICABILITY:

The CURE® system can treat a broad range of dissolved metals, including aluminum, arsenic, barium, cadmium, chromium, cyanide, iron, lead, nickel, uranium, and zinc. The system can also treat contaminants such as emulsified oils, suspended solids, paints, and dyes. Radionuclides were removed by the system at the Rocky Flats Environmental Technology Site (RFETS).

Because this system treats a wide range of contaminants, it is suited for industries and utilities such as plating, mining, electronics, industrial wastewater, as well as remediation projects.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1993. A bench-scale test of the technology was conducted in April 1995 to determine the ability of the system to remove radionuclides from solar evaporation water at RFETS. The system removed over 90 percent of uranium and plutonium from the test water. The technology was demonstrated during August and September 1995 at RFETS under a joint agreement between the Department of Energy, the State of Colorado, and EPA.

The technology has proven to be very effective in a diverse number of industrial applications including metal refinishing, oil treatment plants, acid mine drainage and cooling towers in the U.S. and internationally. Full or pilot scale units are available from CURE® International, Inc.

DEMONSTRATION RESULTS:

During the SITE demonstration, four 3-hour test runs were conducted at RFETS over a 2-week period. Prior to the demonstration, operating parameters were adjusted during several optimization runs.

The demonstration showed that the system removed 30 to 50 percent of uranium and 60 to 99 percent of plutonium from the solar pond water at RFETS. The radionuclide and metal content of the dewatered sludge indicated that these contaminants were highly concentrated in the sludge. Uranium and plutonium were only slightly leachable by TCLP and no metals were leachable by TCLP. These results suggest that the sludge is very stable and resistant to breakdown.

The Demonstration Bulletin (EPA/540/MR-96/502), Technology Capsule (EPA/540/R-92/502a), and Innovative Technology Evaluation Report (EPA/540/R-96/502) are available from EPA.

FOR FURTHER INFORMATION:

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